9. Method to Assess Riverine Impounding Wetlands

The method includes models for the following functions.

- Potential for Removing Sediment
- Potential for Removing Nutrients
- Potential for Removing Heavy Metals and Toxic Organics
- Potential for Reducing Peak Flows
- Potential for Decreasing Downstream Erosion
- Potential for Recharging Groundwater
- General Habitat Suitability
- Habitat Suitability for Invertebrates
- Habitat Suitability for Amphibians
- Habitat Suitability for Anadromous Fish
- Habitat Suitability for Resident Fish
- Habitat Suitability for Wetland-associated Birds
- Habitat Suitability for Wetland-associated Mammals
- Native Plant Richness
- Potential for Primary Production and Organic Export

9.1 Potential for Removing Sediment — Riverine Impounding Wetlands

Note: Please read the introduction to the assessment models (Chapter 2) before using these models. It describes several basic assumptions used in modeling that will help you better understand how to use and apply the methods.

9.1.1 Definition and Description of Function

Removing sediment is defined as the wetland processes that retain sediment in a wetland, and keeping it from moving to downgradient surface waters in the watershed.

A wetland performs this function if there is a net annual decrease of sediment load to downgradient surface waters in the watershed. Reduction in water velocity and filtration are the major processes that remove sediment from surface water (either streamflow or sheetflow) flowing into wetlands. When water velocity is reduced, particles present in the water will tend to settle out (Mitsch and Gosselink, 1993). The size of the particles that settle out is directly related to the reduction in the velocity achieved in the wetland. Filtration is the physical blockage of sediment by erect vegetation.

9.1.2 Assessing this Function for Riverine Impounding Wetlands

The potential of riverine impounding wetlands to remove sediment is a function of their ability to reduce water velocities as determined by the retention time of the water they hold back and by vegetation structure near the ground surface (Adamus et al. 1991).

Retention time cannot be estimated directly in a rapid assessment method. The amount of storage and the shape of outlets (Adamus et al. 1991) are used as variables that capture two aspects of retention time – volume of water stored and potential for retention resulting from outlet constrictions. Attempts were made during the field calibration to calculate retention time using estimated runoff flows from rainfall data and USGS runoff data. However, these data did not provide enough resolution between wetlands, and the indicators described had to be used instead.

The area over which sediment retention occurs, however, may be smaller than the actual area of the AU. Since the model generates an index for the entire wetland, a correction factor ($V_{effectarea1}$) is included that reflects the portion of the AU that actually has the potential for performing the function.

9.1.3 Model at a Glance

Riverine Impounding — Removing Sediment

Process	Variables	Measures or Indicators
Velocity reduction	**Vstorage**	Average depth of both live and deadstorage
Velocity reduction	**Vout**	Qualitative descriptors of outlet constriction
Velocity reduction	**Veffectarea1**	% of AU that is seasonally inundated
Filtration	**Vvegclass**	% of AU in different Cowardin vegetation classes
Filtration	**Vunderstory**	% area of herbaceous understory in AU

Index:

$$\frac{\text{Vstorage} + \text{Vout} + \text{Veffectarea1} + \text{Vvegclass} + \text{Vunderstory}}{\text{Score from reference standard site}}$$

9.1.4 Description and Scaling of Variables

$V_{storage}$ – The amount of water stored in an AU can be assessed as a combination of both “live” storage and “dead” storage. Livestorage is a measure of the volume of storage available during major rainfall events. Another name used for this is “dynamic surface storage”. Deadstorage is the amount of water stored below the bottom of the outlet. It is “dead” in the sense that, once filled, the AU does not have that volume available to store additional storm water. Livestorage is corrected by a factor to estimate the average depth of storage across the entire AU.

> **Rationale:** $V_{storage}$ is a measure of the volume of storage available. It is related to residence time since it is a variable in the equation: residence time = storage/inflow volume. The assumption made is that AU’s in this subclass with a higher average volume of storage will have a higher retention time than those with less storage for any given rate of inflow. Wetlands that store water tend to trap more sediment than those that do not (Fennessey et al. 1994). Attempts were made during the field calibration to estimate inflow volumes using estimated runoff flows from rainfall data and USGS runoff data. Unfortunately, these data did not provide enough resolution between wetlands, and the variable was not included in the model.
>
> **Indicators:** The variable for storage has two indicators; one for livestorage and one for dead. The indicator for the amount of livestorage in a riverine impounding wetland is the difference in elevation between the bottom of the outlet and any flood marks or water marks on vegetation or along the shore. The assumption is that any storage below the outlet elevation is deadstorage because it will have been filled by the time flooding occurs. To estimate the average depth of livestorage in the AU the maximum height as measured at the outlet is corrected by a factor representing the average cross section of the seasonally inundated areas in the AU.
>
> The extent of permanent open water is used as the indicator for deadstorage. In the calculations it is assumed that the average depth of the permanent open water is 2 m and this is used to estimate volume of storage. The average depth of deadstorage is estimated by multiplying the 2 m depth by the portion of the AU that is permanent open water. Depth of water is used to estimate storage volumes because the index score is calculated on a per acre basis. Total storage can be estimated by multiplying the average depth by the area of the AU.
>
> **Scaling:** AUs with average depths of dead and livestorage (as the sum of the two) that are equal to or greater than 1.8 m are scored a [1] for the variable. Values for storage that are less than 1.8 m are scaled as average depth/1.8.

V_{out} – The amount of constriction in the surface outflow from the AU.

> **Rationale:** Water velocities will be reduced in an AU if its outlet is constricted, regardless of its internal structure (Adamus et al. 1991). The constriction holds back water and thereby reduces velocity and increases retention time.

Indicators: No indicators are needed. The relative constriction of the outlet is determined in the field.
Scaling: The scaling of this variable is based on the amount of constriction found in the AU.

Unconstricted or slightly constricted – The outlet allows water flow out of the AU during the wet season across a wide distance. The outlet does not provide much hindrance to waters coming downstream. In general, the distance between the low point of the outlet and inundation height (D28) will be small (< 30 cm - 1 ft). Beaver dams are considered unconstricted unless they are anchored to steep bank on either side because they are usually wide and do not retard flows once the water reaches the crest. Unconstricted or slightly constricted outlets are scored a [0].

Moderately constricted – The outlet is small or narrow enough to hold back some water during the wet season. The outlet is categorized as moderately constricted if it cannot be categorized as either unconstricted or severely constricted. Moderately constricted outlets are scored a [0.5].

Severely constricted – These are small culverts or heavily incised channels anchored to steep slopes. In general, you will find marks of flooding or inundation a meter or more above the bottom of the outlet. Another indicator of a severely constricted outlet is evidence of erosion on the downstream side of the outlet. Severely constricted outlets are scored a [1].

No outlet – Surface water does not leave the wetland through any type of channel; rather it leaves the wetland by sheetflow over a berm or dike. No outlets are scaled as [1].

$V_{effectarea1}$ – area of the AU wherein sediment retention is expected to take place. Some parts of an AU may never be inundated by surface waters and thus will not remove sediments from surface waters.

Rationale: In this assessment method, an index for an AU is calculated on a "per acre" basis. An overall index for an AU is then calculated by multiplying its "per acre" index by its area. Thus, a correction factor representing the area of the AU that actually performs the function, relative to its overall size, is needed.

Indicators: In western Washington, there is some difficulty in establishing the area of an AU that is regularly inundated because the water regime can be so variable for many AU's. The indicator chosen by the Assessment Teams to represent this variable is the area of the AU that is inundated or flooded on a seasonal basis. Indicators such as water marks, deposition lines, or other discoloration on vegetation or rocks can be used to determine the area of inundation during summer.

Scaling: This variable is scaled based on the percentage of the AU that is seasonally inundated. AU's that are seasonally inundated over their entire surface (100%) score a [1]. Areas or inundation less than 100% are scaled proportionally as %area/100.

$V_{vegclass}$ – Percent of ground in an AU that is covered by each of four Cowardin (1979) vegetation classes (emergent, scrub/shrub, forest, and aquatic bed).

Rationale: Persistent plants enhance sedimentation by resisting the flow of water and thereby reducing velocity (Jackson and Starrett 1959, Karr and Schlosser 1977, see also review in Adamus et al. 1991). It is assumed that three of the four Cowardin vegetation classes represent persistent vegetation.

Indicators: No indicators are needed. The areal extent of the four vegetation classes can be estimated directly.

Scaling: The scaling of the variable is based on the percent of the AU covered by four different vegetation classes with a scaling factor based on the type of vegetation. Emergent vegetation is assumed to provide the best sediment retention because it is usually the densest and provides the best trapping near the ground surface (relative factor = 1). Scrub/shrub vegetation is judged to provide almost as much sediment trapping and is factored at 0.8. Forests usually do not have a very high stem density near the surface and are factored at 0.3. Aquatic bed vegetation is not usually permanent and persistent, and therefore, is not expected to provide much sediment trapping. It is factored as [0]. The index for this variable is calculated as (fraction of AU with emergents x 1) + (fraction of AU with scrub/shrub x 0.8) + (fraction of AU with forest x 0.3).

***$V_{understory}$* –** The areal extent of herbaceous vegetation under forested and scrub/shrub areas of the AU.

Rationale: This variable was included to correct a potential error in the previous variable ($V_{vegclass}$). The Cowardin classification characterizes only the highest layer of vegetation and does not characterize the understory. AU's that are forested may still provide good sediment retention if they have an herbaceous understory. Only relatively dense areas of understory with a minimum cover of 20% are included in this variable.

Indicators: No indicators are needed. The areal extent of the herbaceous understory can be estimated directly.

Scaling: The scaling of the variable is based on the percent of the AU covered by a herbaceous understory. AU's with a 100% cover of understory over the entire unit are scaled as [1]. AU's with a cover of less than 100% are scaled proportionally as %area/100.

9.1.5 Calculations of Potential Performance

Riverine Impounding – Removing Sediment

Variable	Description of Scaling		Score for Variable	Result
Vstorage	*Highest:*	Average depth of live + deadstorage > = 2.1 m	If calculation > =2.1 Enter "1"	
	Lowest:	No live or deadstorage	If calculation = 0 Enter "0"	
	Calculation:	Scaling is set as average depth/1	Enter result of calculation	
	1. Calculate livestorage as: D10 x (0.67 x D11.1 + 0.5 x D11.2 + 1 x D11.3) 2. Calculate deadstorage as: D8.3 x 0.01 x 2 3. Storage = live + deadstorage 4. Result = storage/1			
Vout	*Highest:*	No outlet, or severely constricted	If D13.3 = 1 or D13.4 = 1, enter "1"	
	Moderate:	Moderately constricted	If D13.2 = 1, enter "0.5"	
	Lowest:	Slightly, or un-constricted	If D13.1 = 1, enter "0"	
Veffectareal	*Highest:*	100% of the AU, is seasonally inundated	If D8.1 = 100, enter "1"	
	Lowest:	0% of the AU is seasonally ponded or inundated	If D8.1 = 0, enter "0"	
	Calculation:	Scaling = (% of AU inundated /100 rounded off to 1 decimal)	Enter result of calculation	
	Calculate D8.1/100 to get result			
Vunderstory	*Highest:*	100% of AU has herbaceous understory and FO + SS =100%	If calculation = 1, enter "1"	
	Lowest:	No herbaceous understory in AU	If D16 = 0, enter "0"	
	Calculation:	Scaling based on understory as % of the total area of AU	Enter result of calculation	
	Calculate (0.01xD16) x (D14.1 +D14.2+D14.3 +D14.4)/100 to get result			
Vvegclass	*Highest:*	100% of AU has emergent class	If D14.5 = 100, enter "1"	
	Lowest:	No emergent, scrub/shrub, or forest vegetation present in AU	If sum of (D14.1 to D14.5) = 0, enter "0"	
	Calculation:	Emergent vegetation scaled as 1, scrub/shrub as 0.8 and forested as 0.3 x the relative % area of each in AU	Enter result of calculation	
	Calculate [(D14.5 x 1) + ((D14.3 + D14.4) x 0.8) + ((D14.1 + D14.2) x 0.3))] x 0.01 to get result			
			Total of Variable Scores:	
Index for Removing Sediment = Total x 2.70 rounded to nearest 1				
			FINAL RESULT:	

9.1.6 Qualitative Rating of Opportunity

The opportunity of AUs in this subclass to remove sediment is a function of the level of disturbance in the landscape. Relatively undisturbed watersheds in the lowlands in western Washington will carry much lower sediment loads than those that have been impacted by development, agriculture, or logging practices (Hartmann et al. 1996, and Reinelt and Horner 1995). The opportunity that an AU has to remove sediment is, therefore,

linked to the amount of development, agriculture, or logging present in the upgradient part of its contributing basin.
Users will have to make a qualitative judgement on the opportunity of the AU to actually trap sediment by considering the land uses in the contributing watershed and the condition of its buffer. The opportunity for an AU in the riverine impounding subclass to remove sediments is **"Low"** if most of its contributing watershed is undeveloped, not farmed, or not recently logged. Densely vegetated watersheds (e.g., undisturbed forest) stabilize soils, reduce runoff velocity, and thus export less sediment (Bormann et al. 1974, Chang et al. 1983). The opportunity is **"Low"** if the AU receives most of its water from sheetflow rather than from an incoming stream, and it has a good vegetated buffer. Vegetated buffers will trap sediments coming from the surrounding landscape before they reach the AU. A buffer that is only 5 m wide will trap up to 50% of the sediment while one that is 100 m wide will trap approximately 80% of the sediments (Desbonnet et al. 1994). The opportunity is also **"Low"** if the AU receives most of its water from groundwater since this source of water does not carry any sediments.
The opportunity for the AU to remove sediments is **"High"** is the contributing watershed is mostly agricultural, or it contains recent construction, or clear-cut logging. In contrast to undisturbed watersheds, urban, agricultural, or logged watersheds have more exposed soils and thus higher sediment loadings. AU's with upgradient disturbances to the watershed will have a greater opportunity to remove sediment and improve water quality than those in undisturbed watersheds. In general, AU's that are in urban or rapidly urbanizing watersheds will usually have some on-going construction. These can all be assumed to have a **"High"** opportunity for removing sediments. Some watersheds may also have a high sediment load from natural geologic processes such as landslides or avalanches. If you know that the AU is in a watershed with "geologically" induced sediment loads, its opportunity should also be rated as **"High"**.
The opportunity to remove sediment is **"Moderate"** if the activities that generate sediment are a small part of the contributing watershed, or if they are relative far away from the AU. The user must use their judgement in deciding whether the opportunity is moderate or high, and document their decision on the summary page of the assessment.

9.2 Potential for Removing Nutrients — Riverine Impounding Wetlands

Note: Please read the introduction to the assessment models (Chapter 2) before using these models. It describes several basic assumptions used in modeling that will help you better understand how to use and apply the methods.

9.2.1 Definition and Description of Function

Removing Nutrients is defined as the wetland processes that remove nutrients (particularly phosphorus and nitrogen) present in surface waters, and keep them from going to downgradient waters in the watershed.

A wetland performs this function if there is a net annual decrease in the amount of nitrogen and phosphorus going to downgradient waters (either surface or groundwater) in the watershed. Wetlands remove nutrients through 3 major processes:

1) trapping of sediment with phosphorus;
2) removal of phosphorus by adsorption to soils that are high in clay content or organic matter; and
3) removal of nitrogen through nitrification and denitrification in alternating oxic and anoxic conditions (Mitsch and Gosselink 1993).

Plant uptake of nutrients is not modeled because nutrients taken up will be released again after a plant dies and exported during the frequent flooding that characterizes this class of wetlands. Furthermore, some species of wetland plants actually fix nitrogen (Mitsch and Gosselink 1993). Plant uptake changes the timing of nutrient release from a wetland, but it does not significantly change the net balance of nutrients coming in, and going out of, a wetland (Phipps and Crumpton 1994, and Mitsch et al. 1995).

9.2.2 Assessing this Function for Riverine Impounding Wetlands

The potential that wetlands in the riverine impounding subclass have to remove phosphorus from water is modeled as their ability to trap sediments and to adsorb the nutrient to its soils. The ability to trap sediments is characterized by the index generated in the “Removing Sediments” model. The sorptive properties of the soils are characterized based on the organic or clay content of the soils since these are the two types of soils with the highest rates of adsorption of phosphorus (Mitsch and Gosselink 1993).

The potential of wetlands to remove nitrogen is modeled using the area of the wetland that undergoes a seasonal oxic/anoxic cycling. Since seasonal redox potentials cannot be measured in a wetland during a rapid assessment, the indicator used is the percent of the AU that is seasonally inundated minus the percent of the AU that is permanently inundated/ponded. It is assumed that the permanently ponded area is mostly anoxic and does not receive enough oxygen to stimulate the nitrification process. In addition, the relative amount of constriction of the outlet is used as a surrogate for detention time, or the length of time the seasonal waters are held back in the AU.

9.2.3 Model at a Glance

Riverine Impounding — Removing Nutrients

Process	Variables	Measures or Indicators
Phosphorus removal	**Ssed**	Index for Removing Sediments
Phosphorus removal	**Vsorp**	% of AU with clay soil; % of AU with organic soil
Nitrogen transformation	**Veffectarea2**	Area of seasonal inundation minus area of permanent open water
Nitrogen transformation	**Vout**	Qualitative description of outlet characteristics
	Index:	Ssed + Vsorp + Veffectarea2 + Vout / Score from reference standard site

9.2.4 Description and Scaling of Variables

***S**sed* – Index from the function "Removing Sediments."

Rationale: The index is used to model the removal of phosphorus from incoming waters because much of this nutrient comes into an AU already bound to particulate sediments (for a review see Adamus et al. 1991).

Indicators: No indicators are needed. The variable is a index from another model of a function.

Scaling: The index is already scaled between 0 and 10 and re-normalized to a range of 0 –1.

V_{sorp} – The sorptive properties of the surface soils present in an AU.

Rationale: The uptake of dissolved phosphorus through adsorption to soil particles is highest when the soils are high in clay content or organic content (Mitsch and Gosselink, 1993).

Indicators: The indicator for sorptive properties of soils is the extent of the AU with high content of clay or organic matter.

Scaling: AUs with large areas of organic soils or clay soils (> 30% clay) are scaled higher than those with less. The actual scaling is calculated based on the area of mineral soil that is not clay or organic for ease of computation. AUs with less than 50% mineral soils (not clay or organic) are scored a [1]. Those with 50 –95% mineral soils are scored a 0.5, and those with >95% mineral soils (not clay or organic) are scored a [0].

$V_{effectarea2}$ – Areal extent of the AU (as a % of total) that undergoes changes between oxic and anoxic conditions.

Rationale: Nitrogen transformation occurs in areas of the AU that undergo changes between oxic and anoxic regimes. The oxic regime is needed to change ammonium ions (NH_4^+) to nitrate, and the anoxic regime is needed for denitrification by bacteria (changing nitrate to nitrogen gas) (Mitsch and Gosselink 1993).

Indicators: The indicator for the zone where oxygen saturation changes is the seasonally inundated area minus the area of permanent inundation. The assumption for using this indicator is that areas that are seasonally inundated are saturated for a long enough period to develop anoxic conditions and thus denitrification. The seasonal drying then re-introduces oxic conditions that promote nitrification. The area that is permanently inundated, however, is not expected to have enough oxygen at the surface to promote nitrification.

Scaling: AUs that are completely inundated seasonally, and have no permanent open water, are scored a [1] for this variable. Scaling for the others is proportional, based on the % area that is only seasonally inundated (%area / 100).

V_{out} – The amount of constriction in the surface outflow from the AU.

Rationale: Water will tend to be held longer in an AU if its outlet is constricted regardless of its internal structure (Adamus et al. 1991). The constriction is judged to increase the residence time and permit a longer period for the denitrification to occur in the AU. NOTE: V_{out} is also a variable in the "removing sediments" model. It is used again here because in Ssed is used only to model the removal of phosphorus. Since it is also important in the removal of nitrogen it is used again to model the latter process.

Indicators: No indicators are needed. The relative constriction of the outlet is determined in the field.
Scaling: The scaling of this variable is based on the amount of constriction found in the AU.

Unconstricted or slightly constricted – The outlet allows water flow out of the AU during the wet season across a wide distance. The outlet does not provide much hindrance to waters coming downstream. In general, the distance between the low point of the outlet and inundation height (D28) will be small (< 30 cm - 1 ft). Beaver dams are considered unconstricted unless they are anchored to steep bank on either side because they are usually wide and do not retard flows once the water reaches the crest. Unconstricted or slightly constricted outlets are scored a [0].

Moderately constricted – The outlet is small or narrow enough to hold back some water during the wet season. The outlet is categorized as moderately constricted if it cannot be categorized as either unconstricted or severely constricted. Moderately constricted outlets are scored a [0.5].

Severely constricted – These are small culverts or heavily incised channels anchored to steep slopes. In general, you will find marks of flooding or inundation a meter or more above the bottom of the outlet. Another indicator of a severely constricted outlet is evidence of erosion on the downstream side of the outlet. Severely constricted outlets are scored a [1].

No outlet – Surface water does not leave the wetland through any type of channel; rather it leave the wetland by sheetflow over a berm or dike. No outlets are scaled as [1].

9.2.5 Calculations of Potential Performance

Riverine Impounding – Removing Nutrients

Variable	Description of Scaling		Score for Variable	Result
Sssed	*Scaled Score:*	Index for Removing Sediment	Index of function/10	
Vsorp	*Highest:*	Non-clay mineral soils are <50% of area	If D47.3 < = 1, enter "1"	
	Moderate:	Non-clay mineral soils are 50-95% of area	If D47.3 = 2, enter "0.5"	
	Lowest:	Non-clay mineral soils are >95% of area	If D47.3 = 3, enter "0"	
Veffectarea2	*Highest:*	100% of the AU is seasonally inundated (no POW)	If calculation = 1, enter "1"	
	Lowest:	0% of the AU is seasonally ponded	If calculation = 0 enter "0"	
	Calculation:	Scaling = (% of AU inundated/100)	Enter result of calculation	
	Calculate (D8.1-(D8.3 + D14.6)))/100 to get result			
Vout	*Highest:*	No outlet, or severely constricted	If D13.3 = 1 or D13.4 = 1, enter "1"	
	Moderate:	Moderately constricted	If D13.2 = 1, enter "0.5"	
	Lowest:	Slightly or unconstricted	If D13.1 = 1, enter "0"	
			Total of Variable Scores:	
Index for Removing Nutrients = Total x 2.70 rounded to nearest 1				
			FINAL RESULT:	

9.2.6 Qualitative Rating of Opportunity

The opportunity of AUs to remove nutrients should be judged based on the characteristics of its upgradient watershed. Relatively undisturbed watersheds in the lowlands in western Washington will carry much lower nutrient loads than those that have been impacted by development, agriculture, or logging practices (Hartmann et al. 1996, and Reinelt and Horner 1995). The opportunity that an AU has to remove nutrients is, therefore, linked to the amount of development and agriculture present in the upgradient part of its contributing basin. In addition, there are areas in western Washington that have naturally high phosphorus levels in groundwater (Van Denburgh and Santos 1965). AUs in these areas will have an increased opportunity to remove phosphorus if groundwater is a major source of water to the AU.

Users will have to make a qualitative judgement of the opportunity the AU actually has to remove nutrients by considering the land uses in the contributing watershed. The opportunity for an AU in the riverine impounding subclass to remove nutrients is **"Low"** if most of its contributing watershed is undeveloped, or not farmed. The opportunity for the AU to remove nutrients is **"High"** if the contributing watershed is mostly agricultural. The opportunity to remove nutrients is **"Moderate"** if the activities that generate nutrients are a small part of the contributing watershed, or if they are relatively far away from the AU. It should also be considered moderate if the AU is located in a region of high concentrations of phosphorus in groundwater. AUs fed by groundwater high in phosphorus content have a greater opportunity to remove phosphorus through soil adsorption [see results from study of groundwater phosphorus and removal in the Patterson Creek 12 AU discussed in Reinelt and Horner (1995)]. Areas in western Washington with high levels of phosphorus in groundwater can be identified from data presented in Van Denburgh and Santos (1965).

The user must use their judgement in rating the opportunity, and document their decision on the data sheet (Part 2).

9.3 Potential for Removing Metals and Toxic Organic Compounds — Riverine Impounding Wetlands

Note: Please read the introduction to the assessment models (Chapter 2) before using these models. It describes several basic assumptions used in modeling that will help you better understand how to use and apply the methods.

9.3.1 Definition and Description of Function

Removing Metals and Toxic Organic Compounds is defined as the wetland processes that retain metals and toxic organic compounds coming into the wetland, and keep them from going to downgradient waters in the watershed.

An AU performs this function if there is a net annual decrease in the amount of toxic metals and toxic organics flowing to downgradient waters (either surface or groundwater) in the watershed. The major processes by which wetlands reduce metals and toxic organic loadings to downgradient waters are through sedimentation of particulate metals, adsorption, chemical precipitation, and plant uptake. Metals that tend to have a high particulate fraction, such as lead (Pb), may be removed through sedimentation. Adsorption is promoted by soils high in clay content or organic matter. Chemical precipitation is promoted by wetland areas that are inundated and remain aerobic, as well as those with pH values below 5 (Mengel and Kirkby 1982). Finally, plant uptake is maximized when there is significant wetland coverage by emergent plants (Kulzer 1990).

9.3.2 Assessing this Function for Riverine Impounding Wetlands

The potential that wetlands in the riverine impounding subclass have to remove metals and toxic organic compounds is assessed by their ability to reduce water velocities and trap sediment that might contain toxic compounds, and specific characteristics that indicate potential for adsorption, precipitation and uptake by plants. The index for sediment removal is used to simplify the model. Adsorption, precipitation and uptake by plants are each modeled by a separate variable.

9.3.3 Model at a Glance

Riverine Impounding — Removing Metals and Toxic Organics

Process	Variables	Measures or Indicators
Sedimentation	**Ssed**	Index for "Removing Sediments"
Adsorption	**Vsorp**	% of AU with clay soil; % of AU with organic soil
Precipitation	**Vph**	pH of interstitial water
Plant Uptake	**Vtotemergent**	% area of emergent vegetation in AU
Plant Uptake	**Veffectarea1**	% of AU that is seasonally inundated
	Index:	Ssed + Vsorp + Vph + Vtotemergent + Veffectarea1 / Score from reference standard site

9.3.4 Description and Scaling of Variables

S_{sed} – Index from the function "Removing Sediments."

Rationale: The index is used to model the removal of toxic compounds from incoming waters because many of them are transported into an AU already bound to particulate sediments (for a review see Adamus et al. 1991).

Indicators: No indicators are needed. The variable is an index for a function.

Scaling: The index is already scaled between 0 and 10, and is re-normalized to a range of 0 – 1.

V_{sorp} – The sorptive properties of the surface soils present in an AU.

Rationale: Adsorption of both toxic metals and toxic organic compounds is highest when the soils have a high cation exchange capacity (Mengel and Kirkby, 1982.) These are the soils high in either clay or organic content.

Indicators: The indicator for sorptive properties of soils is the extent of the AU with high content of clay or organic matter.

Scaling: AUs with large areas of organic soils or clay soils (> 30% clay) are scaled higher than those with less. The actual scaling is calculated based on the area of mineral soil that is not clay or organic for ease of computation. AUs with less than 50% mineral soils (not clay or organic) are scored a [1]. Those with 50 –95% mineral soils are scored a 0.5, and those with >95% mineral soils (not clay or organic) are scored a [0].

V_{pH} – The pH of interstitial water.

Rationale: Many toxic metals are precipitated out of water when the pH is low. Although there are a few, such as lead, that precipitate out at high pH, the Assessment Team judged that a low pH was better for removing toxic metals overall. Furthermore, the high pH needed to precipitate a few metals (>9) are rarely, if ever, encountered in the wetlands of western Washington.

Indicators: pH can be measured directly using pH tabs.

Scaling: Low pH (<= 4.5) in the interstitial waters of an AU results in the highest index [1] and optimal removal. A pH between 4.5 and 5.5 scores a [0.5] and a pH > 5.5 index a [0].

$V_{totemergent}$ – The areal extent (as % of AU) of emergent plant species in both the emergent zone and as an herbaceous understory to areas of forest and scrub/shrub.

Rationale: Emergent species have, in general, been found to sequester metals and remove oils and other organics better than other plant species (Hammer 1989, and Horner 1992). AUs dominated by emergents were judged to sequester toxic metals and remove organic compounds better than those dominated by forest or scrub/shrub. Furthermore, the emergent vegetation and herbaceous understory support a higher microbial population that can decompose organic toxicants. This is due to a larger surface area exposed to incoming water.

Indicators: No indicators are needed. The areal extent (as % of AU) of emergent species and herbaceous understory is estimated directly.

Scaling: The scaling of the variable is based on the percent of the AU covered by emergent species (using the Cowardin definition) and by an herbaceous understory. AUs with a 100% cover of emergents + understory are scaled as [1]. AU's with a cover of less than 100% are scaled proportionally as %area/100.

$V_{effectarea1}$ – The area of the AU over which the removal of metals and toxic organic compounds is expected to take place. Some parts of an AU may never be inundated by surface waters and thus will not remove toxics from surface waters.

Rationale: In this assessment method, an index for an AU is calculated on a "per acre" basis. A index for an AU is then calculated by multiplying its "per acre" score by its area. Thus, a correction factor representing the area of the AU that actually performs the function, relative to its overall size, is needed.

Indicators: In western Washington, there is some difficulty in establishing the area of an AU that is regularly flooded because the water regime can be so variable for many AU's. The indicator chosen by the Assessment Teams to represent this variable is the area of the AU that is inundated or flooded on a seasonal basis. The area of surface water inundation during the summer must be determined by indicators such as water marks, deposition lines, or other discoloration on vegetation or rocks.

Scaling: This variable is scaled based on the percentage of the AU that is seasonally inundated. AU's that are seasonally inundated over their entire surface (100%) score a [1]. Areas or inundation less than 100% are scaled proportionally as %area/100.

9.3.5 Calculation of Potential Performance

Riverine Impounding – Removing Metals and Toxic Organics

Variable	Description of Scaling		Score for Variable	Result
Ssed	*Score is scaled*	Index for Removing Sediment Function	(Index of Function)/10	
Vsorp	*Highest:*	Non-clay mineral soils are <50% of area	If D47.3 < =1, enter "1"	
	Moderate:	Non-clay mineral soils are 50-95% of area	If D47.3 = 2, enter "0.5"	
	Lowest:	Non-clay mineral soils are >95% of area	If D47.3 = 3, enter "0"	
Vph	*Highest:*	pH less than of equal to 4.5	If D26. 1 < = 4.5, enter "1"	
	Moderate:	pH between 4.5 and 5.5	If D26.1 > 4.5 and < = 5.5, enter 0.5	
	Lowest::	pH greater than 5.5	If D26. 1 > 5.5, enter "0"	
Vtotemergent	*Highest:*	100% of AU has herbaceous understory and/or emergents	If calculation = 1, enter "1"	
	Lowest:	AU has 0% of emergents	If D14.5 + D16 = 0, enter "0"	
	Calculation:	Scaling = (% of AU with emergents + understory/100)	Enter result of calculation	
	Calculate D14.5 + (D16/100 x sum (D14.1 to D14.4)) /100 to get result			
Veffectarea1	*Highest:*	100% of the AU is seasonally ponded or inundated	If D8.1 = 100, enter "1"	
	Lowest:	0% of the AU is seasonally ponded	If D8.1 = 0, enter "0"	
	Calculation:	Scaling = (% of AU inundated/100)	Enter result of calculation	
	Calculate D8.1/100 to get result			

Variable	Description of Scaling	Score for Variable	Result
		Total of Variable Scores:	
Index for Removing Metals and Toxic Organics = Total x 2.38 rounded to nearest 1			
		FINAL RESULT:	

9.3.6 Qualitative Rating of Opportunity

The opportunity of AUs in these subclasses to remove metals and toxic organic compounds should be judged using the characteristics of the upgradient watershed. Those land uses or activities that contribute metals and toxic organics to surface waters include urban and residential areas and agricultural activities involving pesticide/herbicide applications.

Relatively undisturbed watersheds in the lowlands in western Washington will carry much lower loads of toxic chemicals than those that have been impacted by residential, urban development or agriculture (Reinelt and Horner 1995). The opportunity that an AU has to remove toxic compounds is, therefore, linked to the amount of development and agriculture present in the upgradient part of its contributing basin

Users must make a qualitative judgement of the opportunity the AU actually has to remove toxic compounds by considering the land uses in the contributing watershed. The opportunity for an AU in the riverine impounding subclass to remove toxic compounds is **"Low"** if most of its contributing watershed is undeveloped, and not farmed.

The opportunity for the AU to remove nutrients is **"High"** if the contributing watershed is mostly agricultural, urban, commercial, or residential.

The opportunity is **"Moderate"** if the activities that generate toxic compounds are a small part of the contributing watershed, or if they are relative far away from the AU.

The user will have to use their judgement in deciding whether the opportunity is moderate or high, and document their decision on the summary sheet (Part 2).

9.4 Potential for Reducing Peak Flows — Riverine Impounding Wetlands

Note: Please read the introduction to the assessment models (Chapter 2) before using these models. It describes several basic assumptions used in modeling that will help you better understand how to use and apply the methods.

9.4.1 Definition and Description of Function

Reducing Peak Flows is defined as the wetland processes or characteristics by which the peak flow in the downgradient part of the watershed is reduced during major rainfall events that cause flooding.

Surface water that may otherwise cause flooding is stored to a greater degree in a wetland than typically occurs in terrestrial environments. Wetlands reduce peak flows on streams and rivers by slowing and storing stream flow in overbank areas, and by holding back runoff during high water when it would otherwise flow directly downgradient and increase flooding.

Reduction in peak flows is often called water storage in other assessment methods (e.g. Brinson et al. 1995). The Assessment Team, however, decided to model more than just water storage. One of the major hydrologic functions of wetlands in watersheds of western Washington is to attenuate the severity of peak flows during flood events. The level of reduction in flow provided by an AU is the result of both the storage present within it and the amount of surface water entering the AU. AUs that have the same amount of storage may not reduce peak flows by the same amount if one has 10 times the volume of water entering it than the other during a flood event.

9.4.2 Assessing this function for Riverine Impounding Wetlands

The potential of riverine impounding AUs to reduce peak flows is modeled based on the short-term storage capabilities of the AU and an estimate of the relative amount of flow it captures from the upgradient contributing basin. Short-term storage is often called "live-storage" by hydrologists, or "dynamic surface storage" in the national HGM approach (Brinson et al. 1995). In western Washington it is modeled as the amount of water an AU stores above its outlet level.

Any storage below the outlet level of the AU was considered "deadstorage" by the Assessment Team because it is usually filled in western Washington by the time a flood event occurs, and not available to capture storm flows. Since most flooding events occur somewhat later in the late fall, winter and early spring, reductions in peak flow will occur only when an AU has some live-storage as well.

The same argument was judged to apply to the storage within the interstices of the soil. Wetland soils in western Washington are usually saturated by the time most flood events occur, and were not judged to be important in reducing peak flows.

An important factor in peak flow attenuation of depressional wetlands is how much of the surface flow from rainfall event they may actually capture. Wetlands further upgradient in a watershed or basin are judged to be more important in reducing peak flows because they generally hold back a larger percentage of the surface flows. Attempts were made during the field calibration to estimate flows to an AU using estimated runoff flows from rainfall data and USGS runoff data. Unfortunately, these data did not provide enough resolution between AU's. Another variable for flows considered was the stream order. Again the information available on stream order was not easily accessible nor was it very accurate. The ratio of the area in an AU that is inundated to the area of its contributing basin is used to estimate the relative amount of surface water a riverine impounding AU will capture.

9.4.3 Model at a Glance

Riverine Impounding — Reducing Peak Flows

Process	Variables	Measures or Indicators
Short term storage	**Vlivestorage**	Elevation difference between bottom of outlet and flood marks
Amount of surface flow captured	**Vout**	Qualitative descriptors of outlet constriction
Amount of surface flow captured	**Vinund/shed**	Ratio of area of inundation to contributing basin
Index:		Vlivestorage + Vout + Vinund/shed / Score for reference standard site

9.4.4 Description and Scaling of Variables

***V**$_{livestorage}$* – The amount of livestorage present in the AU during an inundation or flooding event.

Rationale: Vlivestorage is a measure of the volume of storage available during major rainfall events that cause flooding. This variable recognizes that some AUs, particularly those with groundwater connections, have water present below the outlet elevation during peak flows that does not contribute to reductions in peak flows (so called "deadstorage"). Others, fill up during small rainfall events, and thus, have no storage below the level of the outflow.

Indicators: The indicator for the amount of livestorage in a riverine impounding AU is the difference in elevation between the bottom of the outlet and any flood marks or water marks on vegetation or along the shore. The assumption is that any storage below the outlet elevation is deadstorage because it will have been filled by the time flooding occurs.

To estimate the average depth of livestorage, the maximum depth, as estimated at the outflow, is corrected by a factor to reflect the shape of the inundated area (see Calculation Table 9.4.5). Livestorage can be estimated as an average depth rather than volume because the index for the AU is established on a per acre basis. The relative index for a specific function is multiplied by the acreage of the AU to establish an overall index for the entire unit.

Scaling: AUs that have an average depth of 2 m, or more, of livestorage are scored a [1] for the variable. The rest are scored on a proportional scale (depth of livestorage in m / 2).

***V**$_{out}$* – The amount of constriction in the surface outflow from the AU.

Rationale: The variable is a measure of the relative capacity of the outlet to impound and store water temporarily during a flood event. AUs that have constricted outlets due to undersized road culverts, or narrow incised channels hold back water longer than a flooding event and will therefore delay and "spread out" the peak flows. Water velocities and flows out of an AU will be reduced in a AU if its outlet is constricted regardless of its internal structure (Adamus et al. 1991).

Indicators: No indicators are needed. The relative constriction of the outlet is determined in the field.

Scaling: The scaling of this variable is based on the amount of constriction found in the AU.

Unconstricted or slightly constricted – The outlet allows water flow out of the AU during the wet season across a wide distance. The outlet does not provide much hindrance to waters coming downstream. In general, the distance between the low point of the outlet and inundation height (D28) will be small (< 30 cm - 1 ft). Beaver dams are considered unconstricted unless they are anchored to steep bank on either side because they are usually wide and do not retard flows once the water reaches the crest. Unconstricted or slightly constricted outlets are scored a [0].

Moderately constricted – The outlet is small or narrow enough to hold back some water during the wet season. The outlet is categorized as moderately constricted if it cannot be categorized as either unconstricted or severely constricted. Moderately constricted outlets are scored a [0.5].

Severely constricted – These are small culverts or heavily incised channels anchored to steep slopes. In general, you will find marks of flooding or inundation a meter or more above the bottom of the outlet. Another indicator of a severely constricted outlet is evidence of erosion on the downstream side of the outlet. Severely constricted outlets are scored a [0.8].

No outlet – Surface water does not leave the wetland through any type of channel; rather it leave the wetland by sheetflow over a berm or dike. No outlets are scaled as [1].

$V_{inund/shed}$ – The ratio of the area that is seasonally ponded or inundated within the AU to the area of its contributing basin.

Rationale: The potential of an AU to reduce peak flows from its contributing basin is partially a function of how much storm-flow it can capture. This is based on the amount of storage available at the time of a storm relative to the volume coming into the AU during a storm. In this model, the area of the contributing basin is used to estimate the relative amount of water (volume as cubic meters/second) entering it, while the area of inundation is used to estimate the relative volume that can be stored. Livestorage was not used because it is a different unit of measurement and the ratio would not have been mathematically correct.

Large contributing basins are expected to generate larger volumes of water for any given storm event than smaller basins. Wetlands that are completely inundated seasonally, are judged to provide more storage (on a per acre basis) than those that are only partially inundated.

Indicators: No indicators are needed. The ratio can be estimated from data on the area of inundation and the area of the contributing basin.

Scaling: AUs whose area of seasonal inundation is more than 1% (1/100) of the contributing basin are scored a [1]. Units whose ratio is smaller are scaled based on the absolute value (the positive value of either a negative number or positive number, e.g. the absolute value of –1 is 1) of the logarithm (base 10) of the ratio. It was necessary to transform the ratio to a logarithm to encompass the range of variability in the data from the reference AUs (see Calculation Table 9.4.5).

9.4.5 Calculations of Potential Performance

Riverine Impounding – Reducing Peak Flows

Variable	Description of Scaling		Score for Variable	Result
Vlivestorage	*Highest:*	Average depth of livestorage > = 2 m	If livestorage > = 2, enter "1"	
	Lowest:	No livestorage	If livestorage = 0, enter "0"	
	Calculation:	Scaling is set as average depth	Enter result of calculation	
	Calculate livestorage as: D10 x (0.67 x D11.1 + 0.5 x D11.2 + 1 x D11.3). Scaled score = livestorage/2.0			
Vout	*Highest:*	No outlet	If D13.4 = 1 enter "1"	
	High:	Severely constricted	If D13.3 = 1, enter "0.8"	
	Moderate:	Moderately constricted	If D13.2 = 1, enter "0.5"	
	Lowest::	Slightly or unconstricted	If D13.1 = 1, enter "0"	
Vinund/shed	*Highest:*	Ratio of area seasonally inundated to area of contributing basin is > = 0.01	If (D8.1 x 0.01 x D1)/D2 > = 0.01, enter "1"	
	Lowest:	0% of the AU is seasonally indundated	If D8.1 = 0, enter "0"	
	Calculation:	Scaling is based on the absolute value of the log of the ratio	Enter result of calculation	
	Calculate 2/ABS [log {(D8.1 x 0.01 x D1)/D2}]			
			Total of Variable Scores:	
Index for Reducing Peak Flows = Total x 5.0 rounded to nearest 1				
			FINAL RESULT:	

9.4.6 Qualitative Rating of Opportunity

The opportunity for an AU to reduce peak flows will increase as the water regime in the upgradient watershed is destabilized. Research at in western Washington has shown that peak flows increase as the percentage of impermeable surface increase (Reinelt and Horner 1995). The opportunity should therefore be judged by the amount of upgradient watershed that is developed.

Users must make a qualitative judgement on the opportunity of the AU to actually reduce peak flows by considering the land uses in the contributing watershed. The opportunity for an AU in the riverine impounding subclass is **"Low"** if most of its contributing watershed is undeveloped, not farmed, or not recently logged. The opportunity is also **"Low"** if the AU receives most of its water from groundwater, rather than from an incoming stream, ditches, or storm drains.).

The opportunity for the AU is **"High"** is the contributing watershed is mostly urban or high density residential. The opportunity is **"Moderate"** if the development is a small part of the contributing watershed, if the upgradient watershed is mostly agricultural, or if these areas are relative far away from the AU. Clear cut logging can also increase peak flows if a significant part of the watershed has recently been cut. These areas, however, will re-vegetate and within 5-7 years the peak flows may again be close to those found before logging. Too many variables are involved in trying to assess the increase in peak flows from logging (e.g. road density, time of cutting, % of watershed cut, etc.) and the rating for opportunity is too difficult to describe in a rapid method. Users will have to use their judgement in deciding whether the opportunity is low, moderate or high, and document their decision on the summary sheet (Part 2).

9.5 Potential for Decreasing Downstream Erosion — Riverine Impounding Wetlands

Note: Please read the introduction to the assessment models (Chapter 2) before using these models. It describes several basic assumptions used in modeling that will help you better understand how to use and apply the methods.

9.5.1 Definition and Description of Function

Decreasing Downstream Erosion is defined as the wetland processes that decrease erosion of stream channels further downstream in the watershed by reducing the duration of erosive flows.

An AU performs this function if it stores excess runoff during and after storm events, before slowly releasing it to downgradient waters. This is similar to the function provided by stormwater retention/detention (R/D) ponds that are designed to prevent downstream erosion in developed areas. The AU decreases downstream erosion by reducing the duration of erosive flows (erosive flows are the high velocity, high volume flows that cause much of the erosion in a watershed).

The major processes by which wetlands reduce the duration of erosive flows is by storing some of the peak flows and thus reducing the time during which erosive flows occur, and by reducing the velocity of water flowing through the AU during a storm event. Erosive flows in a watershed occur above a certain velocity based on geomorphology. By reducing the velocity in general, an AU can reduce the overall time during which the erosive velocities occur.

The function of decreasing downstream erosion is closely related to that of reducing peak flows because a reduction in peak flows will also result in a reduction of velocity. All of the variables used in the "peak flow" model are used for this function as well. One way to consider the function being assessed is to ask, "What would happen to erosive flows in the watershed if the AU were filled?".

9.5.2 Assessing this Function for Riverine Impounding Wetlands

The potential of riverine impounding to decrease downstream erosion is modeled as the process of velocity reduction. Velocity reduction is modeled by the "live-storage" in the unit, by the characteristics of its outlet, by the amount of woody vegetation present, and by the relative amount of a stormflow it can capture.

9.5.3 Model at a Glance

Riverine Impounding — Decreasing Downstream Erosion

Process	Variables	Measures or Indicators
Velocity reduction (applies to all variables)	**Vlivestorage**	Elevation difference between bottom of outlet and flood marks
	Vout	Qualitative descriptors of outlet constriction
	Vwoodyveg	% of AU in forest and shrubs
	Vinund/shed	Ratio of area of inundation to contributing basin
	Index:	½ x Vlivestorage + Vout + Vwoodyveg + 2 x Vinund/shed Score from reference standard site

9.5.4 Description and Scaling of Variables

$V_{livestorage}$ – The amount of livestorage available in the AU during an inundation or flooding event. **This variable is judged to be less important than the others in the equation (see scaling below)**.

Rationale: $V_{livestorage}$ is a measure of the volume of storage present during major flooding events. The Assessment Team assumed that AUs having relatively more storage decrease water velocities more than those with less storage. This variable also recognizes that some AUs, particularly those with ground-water connections, may have water present below the outlet elevation during peak flows. Storage below the outlet, however, does not contribute to velocity reductions. Once an AU fills up to the level of the outlet, the velocity of the water coming in will be equal to the velocity leaving unless there are other factors such as outlet constrictions.

Indicators: The indicator for the amount of livestorage in a riverine impounding AU is the difference in elevation between the bottom of the outlet and any marks of inundation on vegetation or along the shore.

To estimate the average depth of livestorage, the maximum depth, as estimated at the outflow, is corrected by a factor to reflect the shape of the inundated area of the AU(see Calculation Table 9.5.5). Livestorage can be estimated as an average depth rather than volume because the index for the AU is established on a per acre basis. The index for a specific function will be multiplied by the acreage of the AU to establish a index for the entire unit.

Scaling: AUs that have an average depth of 2 m, or more, of livestorage are scored as 0.5 x [1] for the variable. The rest are scored on a proportional scale (e.g. 0.5 m of livestorage would score a 0.25 for the variable). The Assessment Team judged that the variable was less important for the function that the others in estimating velocity reductions and thus was weighted less (the factor of 0.5 in the equation).

V_{out} – The amount of constriction in the surface outflow from the AU.

Rationale: The variable is a measure of the relative capacity of the outlet to impound water and store it temporarily during a flood event. This reduces the velocity of water downstream of the AU. AUs that have constricted outlets due to undersized road culverts or narrow outlets hold water longer than a flooding event and will therefore reduce the duration of erosive flows. Water velocities and flows out of an AU will be reduced if its outlet is constricted regardless of its internal structure (Adamus et al. 1991).

Indicators: No indicators are needed. The relative constriction of the outlet is determined in the field.

Scaling: The scaling of this variable is based on the amount of constriction found in the AU.

Unconstricted or slightly constricted – The outlet allows water flow out of the AU during the wet season across a wide distance. The outlet does not provide much hindrance to waters coming downstream. In general, the distance between the low point of the outlet and inundation height (D28) will be small (< 30 cm - 1 ft). Beaver dams are considered unconstricted unless they are anchored to steep bank on either side because they are usually wide and do not retard flows once the water reaches the crest. Unconstricted or slightly constricted outlets are scored a [0].

Moderately constricted – The outlet is small or narrow enough to hold back some water during the wet season. The outlet is categorized as moderately constricted if it cannot be categorized as either unconstricted or severely constricted. Moderately constricted outlets are scored a [0.5].

Severely constricted – These are small culverts or heavily incised channels anchored to steep slopes. In general, one will find marks of flooding or inundation a meter or more above the bottom of the outlet. Another indicator of a severely constricted outlet is evidence of erosion on the downstream side of the outlet. Severely constricted outlets are scored a [0.8].

No outlet – Surface water does not leave the wetland through any type of channel; rather it leave the wetland by sheetflow over a berm or dike. No outlets are scaled as [1].

$V_{woodyveg}$ – The areal extent (as a % of the AU) of woody vegetation present that will reduce water velocities during a flood.

Rationale: Surface water flowing through areas of woody vegetation will have its velocity reduced because the stiff vegetation provides a structural barrier to flow (Adamus et al. 1991). The extent of the woody vegetation over the entire AU is used because the vegetation can also reduce velocities of water coming in as sheetflow in areas that are not inundated by flooding.

Indicators: The indicator for stiff erect vegetation is the percent area within the AU of two Cowardin vegetation classes – forest and scrub/shrub. The Assessment Team judged that these two classes represent vegetation that will remain erect during a flood event and will provide the structural barrier needed to reduce velocities.

Scaling: AUs that have a 100% cover of forest or scrub/shrub are scored a [1] for this variable. Scaling for the others is proportional, based on the % area that is covered by forest and/or scrub/shrub (% area / 100).

$V_{inund/shed}$ – The ratio of the area that is seasonally ponded or inundated with the AU to the area of its contributing basin. **This variable was judged to be more important than the others in the equation and was given a weighting factor of 2.**

Rationale: The potential of an AU to reduce velocity is partially a function of the retention time of water in the wetland during a storm event. Retention time is the relative volume coming into a unit during a storm event divided the amount of storage present. The area of the contributing basin is used as a surrogate for the relative amount of water (volume as cubic meters/second) entering the AU, while the area of inundation is used to estimate the relative volume stored. Attempts were made during the field calibration to estimate flows to an AU using estimated runoff flows from rainfall data and USGS runoff data. Unfortunately, these data did not provide enough resolution between AU's. Another variable for flows considered was the stream order. Again the information available on stream order was not easily accessible nor was it very accurate.

Large contributing basins are assumed to generate larger volumes of water for any given storm event than smaller basins. AU's that are completely inundated seasonally, are judged to provide more storage (on a per acre basis) than those that are only partially inundated.

Indicators: No indicators are needed. The ratio can be estimated from map measurements.

Scaling: AUs whose area of seasonal inundation is more than 1% of the contributing basin are scored a [2]. AUs whose ratio is smaller are scaled based on the absolute value of the logarithm (base 10) of the ratio (see Calculation Table 9.5.5). It was necessary to transform the ratio to a logarithm to encompass the range of variability in the data from the reference units. The 2 x multiplier is a scaling factor reflecting the importance of the variable. The Assessment Team judged that this variable is more important than the others in the performance of the function.

9.5.5 Calculation of Potential Performance

Riverine Impounding – Decreasing Downstream Erosion

Variable	Description of Scaling		Score for Variable	Result
Vlivestorage	*Highest:*	Average depth of livestorage > = 2 m	If livestorage > = 2, enter "0.5"	
	Lowest:	No livestorage	If livestorage = 0, enter "0"	
	Calculation:	Scaling is set as (average depth of livestorage /1) x 0.5	Enter result of calculation	
	Calculate average livestorage as [D10 x (0.67 x D11.1 + 0.5 x D11.2 + 1 x D11.3)]. If livestorage < 2 m, scaled score = (livestorage/2 x 0.5)			
Vout	*Highest:*	No outlet	If D13.4 = 1 enter "1"	
	High:	Severely constricted	If D13.3 = 1, enter "0.8"	
	Moderate:	Moderately constricted	If D13.2 = 1, enter "0.5"	
	Lowest::	Slightly or unconstricted	If D13.1 = 1, enter "0"	
Vwoodyveg	*Highest:*	100% cover of shrub or forest	If calculation = 1, enter "1"	
	Lowest:	No cover of forest or shrubs	If calculation = 0, enter "0"	
	Calculation:	Scaling is set as % cover of (SS+FO)/100	Enter result of calculation	
	Calculate (D14.1+D14.2+ D14.3+D14.4) / 100			
Vinund/shed	*Highest:*	Ratio of area inundated to area of contributing basin is > = 0.01	If (D8.1 x 0.01 x D1)/D2 > = 0.01, enter "2"	
	Lowest:	0% of AU, is seasonally inundated	If D8.1 = 0, enter "0"	
	Calculation:	Scaling is based on the absolute value of the log of the ratio	Enter result of calculation	
	Calculate 2 x 2/ ABS[log{(D8.1 x 0.01 x D1)/D2}]			
			Total of Variable Scores:	
Index for Decreasing Downstream Erosion = Total x 3.33 rounded to nearest 1				
			FINAL RESULT:	

9.5.6 Qualitative Rating of Opportunity

The opportunity for an AU to decrease erosion will increase as the water regime in the upgradient watershed is destabilized. Research in western Washington has shown that peak flows and velocities increase as the percentage of impermeable surface increase (Reinelt and Horner 1995). The opportunity should therefore be judged by the amount of upgradient watershed that is developed.

Users must make a qualitative judgement on the opportunity of the AU to actually decrease erosion by considering the land uses in the contributing watershed. The opportunity for an AU in the riverine impounding subclass is **"Low"** if most of its contributing watershed is undeveloped, not farmed, or not recently logged. The opportunity is also **"Low"** if the AU receives most of its water from groundwater, rather than from an incoming stream, ditches, storm drains , or other surface water sources.

The opportunity for the AU is **"High"** is the contributing watershed is mostly urban or high density residential. The opportunity to is **"Moderate"** if the development is a small part of the contributing watershed, if the upgradient watershed is mostly agricultural, or if these areas are relative far away from the AU. Users must use their judgement in deciding whether the opportunity is low, moderate or high, and document their decision on the summary sheet (Part 2).

9.6 Potential for Recharging Groundwater — Riverine Impounding Wetlands

Note: Please read the introduction to the assessment models (Chapter 2) before using these models. It describes several basic assumptions used in modeling that will help you better understand how to use and apply the methods.

9.6.1 Definition and Description of Function

Recharging Groundwater is defined as the wetland processes by which surface water coming into a wetland is transported into subsurface water that moves either into unconfined aquifers or into interflow. It is the "interflow" that supports flows in streams during the dry season.

Wetlands recharge groundwater by holding back precipitation and surface water. This water then may infiltrate into the groundwater system.

There are two aspects of recharge. The first is the recharge of shallow subsurface flows (called interflow) that help maintain low flows in streams during the dry season. The second aspect of the function is recharge of subsurface aquifers. The wetland process that is important to both aspects of the function is infiltration.

The first draft of the assessment methods included separate functions for the recharge of interflow (called Maintaining Seasonal Low Flows) and the recharge of unconfined aquifers (called Recharging Unconfined Aquifers). During the field calibrations, however, we were unable to characterize the conditions of the subsurface geology and soils well enough to determine if water infiltrating through the wetland would become part of the "interflow" or part of an unconfined aquifer. As a result, the functions were combined, and the model only assesses the relative rates of infiltration in an AU.

Surface outflow from the wetland is not judged to be an important factor in maintaining low flows in streams. Perennial surface outflow from an AU is not usually a result of waters stored within the wetland. The wetland may be a location where groundwater is discharged, but the source of this groundwater is not within the wetland itself. Rather, it comes from waters stored in the ground throughout the watershed.

The contribution of a wetland to seasonal low flows is the water that enters the groundwater system during the wet season. Wetlands in western Washington will usually dry out by the time that support to dry season low flows is important in streams. Surface waters stored within the wetland will usually have evaporated, infiltrated, or flowed out.

9.6.2 Assessing this Function for Riverine Impounding Wetlands

The potential for AUs to recharge groundwater is modeled as the relative rate of infiltration. Two variables are used; the first is a qualitative rating of the infiltration rate of the soils within the unit; and the second is the percent of the AU with seasonal inundation.

9.6.3 Model at a Glance

Riverine Impounding — Recharging Groundwater

Process	Variables	Measures or Indicators
Infiltration	**Vinfilt**	Rating infiltration rate of soils
Infiltration	**Veffectarea2**	Area of seasonal inundation minus area of permanent open water
	Index:	Vinfilt + Veffectarea2 / Score from reference standard site

9.6.4 Description and Scaling of Variables

V_{infilt} – A qualitative rating of the infiltration capacity of the soils in the AU.

Rationale: Infiltration can occur only where the soils are permeable. Many AUs in the lowlands of western Washington are formed on impermeable shallow tills or have developed extensive peat deposits. These conditions hinder the recharge of groundwater. Recharge is an important process only if the soils have a high sand, gravel or cobble content, and a low content of clays, silts, or organic matter. The layer with the lowest infiltration in the top 60 cm is used to develop the rating.

Indicators: The indicator of infiltration is the relative amount of sand, silt, gravel, clay or organic matter present in the soils. Infiltration of soils is rated down to a depth of 60 cm (2 ft).

Scaling: Soils with more than 50% of gravel and cobbles and less than 30% of clay or organic matter are scaled a [1] since these have the highest infiltration rate. Soils with more than 50% sand and less than 30% of clay or organic matter are scaled a [0.5]. Soils with more than 30% clays or organic matter are scaled a [0.1] because these have little or no infiltration.

$V_{effectarea2}$ – The area of the AU where infiltration occurs. The variable is measured as the percent of the AU that is seasonally inundated minus the area that has permanent open water.

Rationale: Infiltration can occur only where the surface waters provide a hydraulic head to push water into the soils. Areas of permanent open water, however, are judged by the Assessment Team not to be permeable. Areas of permanent water usually develop a layer of fine sediments, often organic, that severely reduce infiltration. The effective area where infiltration occurs, therefore, is considered only to be the area that is seasonally inundated (area that is permanently inundated is excluded from this variable).

Indicators: The indicator for the effective area is the seasonally inundated area minus the area of permanent inundation.

Scaling: AUs that are completely inundated seasonally and have no permanent open water are scored a [1] for this variable. Scaling for the others is proportional, based on the % area that is only seasonally inundated (%area / 100).

9.6.5 Calculations of Potential Performance

Riverine Impounding – Recharging Groundwater

Variable	Description of Scaling		Score for Variable	Result
Vinfilt	*Highest:*	Gravel, cobble >50% of soil and silt, clays, and organics <30%	If D48.1 = 1, enter "1"	
	Moderate:	Sand >50% of soil and silt, clays, and organics <30%	If D48.2 = 1, enter "0.5"	
	Lowest:	Silt, clay, and organics > 30% of soil	If D48.3 = 1, enter "0.1"	
Veffectarea2	*Highest:*	100% of the AU, is seasonally ponded or inundated with no permanent open water	If calculation = 1, enter "1"	
	Lowest:	0% of the AU is seasonally ponded	If calculation = 0, enter "0"	
	Calculation:	Scaling = (% of AU inundated/100)	Enter result of calculation	
	Calculate (D8.1-(D8.3+D14.6))/100			
			Total of Variable Scores:	
Index for Recharging Groundwater = Total x 6.67 rounded to nearest 1				
			FINAL RESULT:	

9.6.6 Qualitative Rating of Opportunity

Groundwater is an integral component of the water cycle throughout western Washington. The Assessment Teams have judged that all AUs in the lowlands of western Washington have a **"High"** opportunity to recharge either interflow or an unconfined aquifer if the surface soils within the AU are permeable enough. The assumption is that all AUs have some link to groundwater.

9.7 General Habitat Suitability — Riverine Impounding Wetlands

> **Note**: Please read the introduction to the assessment models (Chapter 2) before using these models. It describes several basic assumptions used in modeling that will help you better understand how to use and apply the methods.

9.7.1 Definition and Description of Function

General Habitat Suitability is defined as the characteristics or processes present in a wetland that indicate a general habitat suitability for a broad range of wetland-associated species. It also includes processes or characteristics within a wetland that help maintain ecosystem resilience (characteristics that are important in maintaining the ecosystem when it is disturbed). The assessment model attempts to assess how well an AU provides habitat for fauna. The model is not focused on individual species groups, but rather it emphasizes the elements in an AU that help support a range of different animal species. Plant species are addressed in a separate function. The "General Habitat Suitability" function may be used as a surrogate for "General Wildlife Habitat," though it is not restricted to the common definition of "wildlife" as mammals, and birds. The general habitat function incorporates elements that are important to invertebrates and other decomposers as well as amphibians.

Many of the variables used to assess the performance of an AU for general habitat are also used in the assessments of habitat suitability for individual species groups. The SWTC and Assessment Teams, however, thought it important to assess General Habitat Suitability in broad terms as well as the individual species groups.

9.7.2 Assessing this Function for Riverine Impounding Wetlands

An AU in the riverine impounding subclass provides suitable habitat if it has a complex physical structure, high plant species richness, and seasonal or year-round standing water. The suitability of an AU also increases if it has high interspersion of "habitat" types within the AU.

The model is additive so that physical structures in the wetland (i.e. channels, upland/wetland edge, etc.) and biologic characteristics such as plant associations add to the general habitat suitability of an AU. The operative assumption is that the suitability of an AU for all species groups increases as the number of characteristics in the AU increase.

The presence of urban or high-density residential areas around an AU is included as a variable to reflect the potential for a reduction in the performance of this function. Development in the area around a wetland can results in increases in surface water velocities, surface water volumes, increased pollution loadings, and changes in the water regime that have an impact on suitability of a wetland as habitat (Reinelt and Horner 1995).

9.7.3 Model at a Glance

Riverine Impounding — General Habitat Suitability

Characteristics	Variables	Measures or Indicators
Structural heterogeneity (applies to all variables)	**Vbuffcond**	Descriptive table of conditions in buffer
	V%closure	% area of canopy closure over AU
	Vstrata	Maximum number of strata in any one association
	Vsnags	Categories of snags present
	Vvegintersp	Interspersion between vegetation classes -diagrams
	Vlwd	Categories of LWD present
	Vhydrop	Number of water regimes present
	Vwaterdepth	Number of water depth categories present
	Vwintersp	Characteristics of water interspersion - diagrams
	Vprichness	Number of plant species present
	Vmature	Presence/absence of mature trees
	Vedgestruc	Structural complexity of AU edge
Reducers		
Surrounding land uses	**Vupcover**	Land uses within 1 km of wetland
	Index:	(Vbuffcond + V%closure + Vstrata + Vsnags + Vvegintersp + Vlwd + Vhydrop + Vwaterdepth + Vwintersp + Vprichness + Vmature + Vedgestruc) x Vupcover / Score for reference standard site

9.7.4 Description and Scaling of Variables

***V**$_{buffcond}$* – Condition of buffer within 100 m of the edge of the AU, as rated by extent of undisturbed areas.

Rationale: The condition of the buffer affects the ability of the AU to provide appropriate habitat for some species groups (Zeigler 1992). Terrestrial species using the wetland that are dependent upon upland habitats for a portion of their life-cycles are benefited by the presence of relative undisturbed upland community types immediately surrounding the wetland. Some guilds may not require upland habitats for a portion of their life-cycle but the presence of humans and domestic animals in close proximity to the wetland impacts those species which are sensitive to human/domestic animal presence and which cannot escape to other refuge habitats.

Indicators: This variable is assessed using buffer categorizations (Part 2).

Scaling: AUs with buffers that are relatively undisturbed for at least 100 m around 95% of the AU (buffer category #5) are scaled a [1]. The categories between 0-5 are scaled proportionally as 0, 0.2,0.4, 0.6, and 0.8.

***V**$_{\%closure}$* – The % of the AU with a canopy closure of woody vegetation higher than 1.

Rationale: The Assessment Teams judged canopy closure an important general habitat feature because it:

1) influences the micro-climate within the AU;
2) is a source of organic material;
3) stabilizes the soils within the AU; and
4) provides structural complexity for perches, nest sites, and invertebrates.

All of these factors contribute to increasing faunal richness.

Indicators: No indicators are needed to assess this variable. Canopy cover can be estimated directly.
Scaling: Generally, a canopy provides the best habitat conditions when the closure is moderate. The data from the reference sites suggests that a canopy closure between 30 and 60% is best (scaled as a [1]). Either more or less canopy cover is not as good. Canopy closures between 10-29% and 61-100% were scored a [0.5], and canopy closures that were less than 10% were scored a [0].

V_{strata} – The maximum number of strata in any single plant association. A plant association (definition in Part 2) can have up to 6 strata (layers: trees, shrub, low shrub, vine, herbaceous, mosses, and bryophytes). To count as a stratum, however, the plants of that stratum must have 20% cover in the association in which they are found.

Rationale: A greater number of strata provide more niches for different species than fewer strata. Strata are important to wildlife because different species utilize different strata for feeding, cover, and reproduction. Some species use a single strata exclusively throughout their life history (many invertebrates, for example, and some small mammal species) (Andrewartha and Birch 1984). Other species, on the other hand, require several strata to meet their life requirements. Consequently, an increase in number of strata will increase the suitability of an AU by increasing the potential species richness.
Indicators: No indicators are needed to assess this variable. The number of strata can be estimated directly.
Scaling: AUs with 5 or 6 strata are scored a [1] for this variable. AUs with only one are scored a [0]. AUs with 2, 3, and 4 strata are scaled proportionally as 0.25, 0.5 and 0.75 respectively.

V_{snags} – The number of different snag categories, based on states of decomposition, found in the AU.

Rationale: Snags are the source of cavities in standing woody vegetation that provides habitat for numerous bird and mammal species. Many species of birds and mammals utilize cavities for nesting, roosting, denning, and/or refuge. Snags are invaded by invertebrates and other organisms of decay, which in turn provide food for many species of wildlife (Davis et al. 1983). In addition, when snags fall, they contribute to the overall health of an ecosystem through the process of decay, which contributes nutrients to the soil (Maser et al. 1988). Furthermore, the presence of large snags was judged to be more important as a habitat feature than small snags because they have the potential for larger cavities as well as small ones; thus providing an additional niche in the wetland.

Indicators: The number and size of cavities within an AU cannot be measured directly because they can be difficult to see during a "rapid" site visit. Snag characteristics and decay classes can, however, be used to indicate the presence of cavities. Eight different categories of snags representing different levels of decay are used as the indicator for the different potential sizes of cavities that may be found in the AU. It is assumed that snags will be used and cavities formed or excavated if dead branches or trunks are present. In addition, more importance is given if at least one of the snag categories is larger than 30 cm dbh.

Scaling: A riverine impounding AU with 6 or more of the 8 categories of snag characteristics present is scored a [1]. Fewer categories are scaled as proportional to 6 (i.e. # of categories/6). If the AU has any snag that is larger than 30 cm dbh, the score for V_{snag} is increased by 0.3.

$V_{veginterp}$ – The extent of interspersion between Cowardin vegetation classes.
Rationale: The extent of interspersion between vegetation classes is a structural element of the wetland plant community that reflects habitat complexity. This is a measure of interspersion between classes, not a measure of the number of classes present. Consequently, an AU with only two Cowardin vegetation classes may have a higher degree of interspersion than an AU with 3 Cowardin vegetation classes.

In general, more “edge" between different vegetation community types increases the habitat suitability for some wildlife taxa. For example, a higher interspersion of plant types (as characterized by Cowardin vegetation classes) is likely to support a higher diversity of macro-invertebrates (Chapman 1966, Dvorak and Best 1982, and Lodge 1985).

Indicators: The amount of interspersion between vegetation classes is assessed using diagrams developed from those found in the Washington State Rating System (WDOE 1993).

Scaling: AUs with more interspersion between vegetation classes score higher than those with fewer. The model has four categories of interspersion (none, low, moderate, high) and these are used as the basis for developing a scaled score. A high level of interspersion is scored a 1, a moderate a 0.67, a low = 0.33, and none = 0.

V_{lwd} – The number of categories (size and decay level) of downed large woody debris in the AU. This consists of woody debris found floating or partially submerged in permanent open waters as well as that found in the vegetated parts of the AU.

Rationale: Woody debris provides a major habitat niche for decomposers and invertebrates. Is also provides refuge for amphibians and other vertebrates, and contributes to the production of organic soils.

Downed woody material is an important structural element of wildlife habitat for many different species. In the water, it is important cover for both resident and anadromous fish. In upland areas of the AU it provides shelter for small mammals, birds, and amphibians (Thomas et al. 1978). The downed woody material is also an important structural element for invertebrate species, which in turn provide food for much of the AU trophic webs (Maser et al. 1988).

Indicators: Direct measures of the quantity and quality of decaying woody debris is not feasible for a rapid assessment method. A descriptive matrix of different classes and decay levels is used as an indicator for the variable. The matrix is based on the assessment procedure developed for the Timber Fish and Wildlife watershed assessment methods (Schuett-Hames et al. 1994).

Scaling: AUs with 10 or more categories of large woody debris in permanent open water and in vegetated areas score a [1]. The rest are scored proportionally to 10 (# categories /10).

V_{hydrop} – The number of different hydroperiods, or water regimes, present in the AU.

Rationale: Many aquatic species have life cycles keyed to different water regimes of permanent, seasonal, or saturated conditions. A number of different water regimes in an AU will, therefore, support more species than an AU with fewer water regimes. For example, some species are tolerant permanent pools, while others can live in pools that are temporary (Wiggins et al. 1980).

Indicators: The variable is assessed using specific hydroperiod classes as descriptors. These are permanently flooded, seasonally flooded, occasionally flooded, and saturated but not flooded as described below.

Permanently Flooded or Inundated – Surface water covers the land surface throughout the year, in most years. This includes the Cowardin classes of **Intermittently Exposed (**surface water is present throughout the growing season except in years of extreme drought), and **Semipermanently Flooded** (surface water persists throughout the growing season in most years).

Seasonally Flooded or Inundated – Surface water is present for extended periods (1 month), especially early in the growing season, but is absent by the end of the season in most years. During the summer dry season it may be difficult to determine the area that is seasonally flooded. Use the indicators described in D8.1 to help you determine the area that is seasonally flooded or inundated.

Occasionally Flooded or Inundated – Surface water is present for brief periods during the growing season, but the water table usually lies below the soil surface for most of the season. Plants that grow in both uplands and wetlands are characteristic of the temporarily flooded regime.

Saturated – The substrate is saturated to the surface for extended periods during the growing season, **but surface water is seldom present**. The latter criterion separates saturated areas from inundated areas. In this case there will be no signs of inundation on plant stems or surface depressions.

Scaling: AUs with all four hydroperiod classes are scored a [1]. Those with fewer are score proportionally (3 classes = 0.67, 2 = 0.33, 1 = 0).

$V_{waterdepth}$ – the number of water depth categories present in the AU in the permanent or seasonal inundated areas.

Rationale: Different water depths provide habitat for different plant communities (emergent vs. aquatic bed as examples) that in turn provide different habitats for waterfowl (Weller 1990), amphibians (Richter 1998), and other vertebrate taxa as well as invertebrates (Wilcox and Meeker 1992). A wetland with a range of water depths will therefore, provide a broader range of habitats than one with only one water depth.

Indicators: The variable is scored using a condensed form of the depth classes developed for the Wetland Evaluation Technique (Adamus et al. 1987). These are 0-20 cm, 21-100 cm, and >100 cm depth classes.

Scaling: AUs with all 3 depth classes are score a [1]; those with 2 are scored [0.67]; 1 class = [0.33], and 0 classes = [0] .

$V_{wintersp}$ – The extent of interspersion present between vegetated areas of the AU and permanent open water.

Rationale: The extent of water interspersed with vegetation is another structural element of the AU that can add habitat complexity. The complexity of the mosaic pattern of the interface between open water and erect vegetation is an indicator of more habitat niches being available.

High interspersion between vegetation and water is important because of the increased variety of vegetation types and cover conditions result from such interspersion (Adamus et al. 1991). Contact zones between open water and vegetation provide protection from wind, waves, and predators, and may provide natural territorial boundaries for wildlife (Golet and Larson 1974). The transition between water and vegetation also provide habitat elements for both open-water and more terrestrial species (Weller and Spatcher 1965, and Willard 1977).

Indicators: The interspersion in an AU is assessed using a series of diagrams that rates the interspersion as high, moderate, low, and none.

Scaling: AUs with high interspersion are score a [1]; those with moderate are scored [0.67]; those with low = [0.33], and those with no interspersion (i.e. no permanent open water) = [0]

$V_{prichness}$ – The total number of plant species in an AU.

Rationale: The number of plant species in an AU is an indicator of the potential number of niches present for insects, other invertebrates, and microfauna. Many insects and detritivores are associated with a specific plant species in a parasitic, commensal or symbiotic relationship. The total number of wildlife species in an AU is expected to increase as the number of plant species increases. Plant species includes both native and non-natives because both provide food, cover, and other habitat requirements for invertebrates.

Indicators: The indicator of overall plant richness is the number of species that is found during the field visit.

Scaling: Riverine impounding AUs with 40 or more plant species are scored a [1]. Those with less are scored proportionally to 40 (# species / 40). The Assessment Team recognizes that there may be some discrepancy between the number of species that can be identified in the summer and the number that can be identified in the winter.

V_{mature} – The AU has, or does not have, mature trees.

Rationale: Mature trees within an AU are used as an indicator of habitat richness that is not captured in other variables. Mature trees are an indication that the area within the AU has had time to develop a complex physical structure on its surface (e.g. large and small woody debris with different levels of decomposition, a range of vegetation in different growth stages from seedlings to senescent). These structural elements provide an increased number of niches for many organisms.

Indicators: This variable is characterized by measuring the dbh (diameter at breast height) of the five largest trees of each species. If the average diameter of the three largest of a given species exceed the diameters given in Part 2, the AU is considered to contain a stand of mature trees. See Part 2 for a more detailed description of how to assess this variable. The size of trees at maturity used in the data are based on measurements made in wetlands of the Puget Sound Lowlands (Cooke pers. comm.) and on the judgement of the Assessment Team

Scaling: This is an “on/off” variable. AUs with mature trees are scored a [1], those without are scored a [0].

$V_{edgestruc}$ – The vertical structure and linear characteristics of the AU edge.

Rationale: The convolutions (e.g., length of edge in relation to area of AU) and differences in heights of vegetation classes along the edge of the AU are important habitat characteristics for many wildlife species. Additional habitat exists within vegetated lobes and scalloped edges of wetlands. Further, embayments and peninsulas provide "micro-habitats" for certain species that require hiding cover, or visual isolation (USDI 1978, Verner et al. 1986, and WDOE 1993).

For example, a simple AU may be a circular pond with a fringing emergent marsh composed of cattails, which adjoins immediately to a grazed pasture. The edge in this case is characterized as having low structural richness (lack of shrubs and trees), and no convolutions (as the edge is nearly circular, with no embayments or peninsulas). In contrast, a more complex AU may adjoin an area composed of trees and shrubs, adding to the structural richness, and may be irregular along its edge, with many twists and turns, resulting in enclosed bays of emergent vegetation and jutting peninsulas of forest or shrub.

Indicators: The edge structure of the AU is assessed by using a descriptive key that groups the edges and vertical structure along the edge into high, medium, low, and no structural diversity.

Scaling: AUs with a highly diverse edge are scored a [1]; moderate = 0.67, low = 0.33, and none = 0.

$V_{upcover}$ – the types of land uses within 1 km of the estimated edge of the AU. **This variable is used to indicate potential reductions in the level of performance for the function.**

Rationale: It is assumed that development (land conversion) around an AU will alter the water regime of the AU by shortening the time between the event and the peak within the AU. This will increase rates of flows through the AU, increase peak flows, increase volumes of water, and decrease low-flow duration from storm-water runoff from converted landforms in the AU contributing basin. Increases in flow rates can increase export of nutrients from the AU, it often increases the input of sediments and nutrients, and it results in less stable water level conditions. Wetland invertebrates and plants are also known to decrease in richness and abundance with greater water level fluctuations and concomitant pollution loads (Ludwa 1994, Schueler 1994, Azous and Richter 1995, and Hicks 1995)

Indicators: The indicator for this variable is the % of the land within a 1 km radius of the AU that is in urban, residential, or clear cut.

Scaling: The index of general habitat suitability is reduced by 10% (factor of 0.9) if the land uses within 1 km total more than 60% high density residential, low density residential, urban/commercial or clear-cut.

9.7.5 Calculation of Habitat Suitability

Riverine Impounding – General Habitat Suitability

Variable	Description of Scaling		Score for Variable	Result
Vbuffcond	*Highest:*	Buffer category of 5	If D42 =5, enter "1"	
	High:	Buffer category of 4	If D42 =4, enter "0.8"	
	Moderate:	Buffer category of 3	If D42 =3, enter "0.6"	
	Medium Low:	Buffer category of 2	If D42 =2, enter "0.4"	
	Low:	Buffer category of 1	If D42 =1, enter "0.2"	
	Lowest:	Buffer category of 0	If D42 =0, enter "0"	
V%closure	*Highest:*	Canopy closure is between 30-60%	If D17 > = 30 and D17 < = 60, enter "1"	
	Moderate:	Canopy closure is between 10-29% or 61-100%	If D17 = 10 to 29 or D17 = 61-100, enter "0.5"	
	Lowest:	Canopy closure is <10%	If D17 < 10, enter "0"	
Vstrata	*Highest:*	5 or 6 strata present	If D21 > = 4, enter "1"	
	High:	4 strata present	If D21 = 4, enter "0.75"	
	Moderate:	3 strata present	If D21 = 3, enter "0.50"	
	Medium Low:	2 strata present	If D21 = 2, enter "0.25"	
	Lowest:	1 strata present	If D21 = 1, enter "0"	
Vsnags	*Highest:*	At least 6 categories of snags and some > 30 cm dbh	If D31 > = 6 and D31.1 =1, enter "1.3"	
	Lowest:	No snags present	If D31 = 0, enter "0"	
	Calculation:	Scaled as # categories/6 + 0.3 if dbh > 30 cm	Enter result of calculation	
	If D31 < 6 calculate D31/6 + D31.1x 0.3; if D31 > 6 calculate 1 + D31.1 x 0.3			
Vvegintersp	*Highest:*	High interspersion	If D39 = 3, enter "1"	
	Moderate:	Moderate interspersion	If D39 = 2, enter "0.67"	
	Low:	Low interspersion	If D39 = 1, enter "0.33"	
	Lowest:	No interspersion (1 class only)	If D39 = 0, enter "0"	
Vlwd	*Highest:*	AU has at least 10 categories of different sizes and decomposition states of large woody debris	If calculation > = 1, enter "1"	
	Lowest:	No categories of LWD	If calculation = 0, enter "0"	
	Calculation:	Scaling based on the number of categories divided by 10	Enter result of calculation	
	Calculate (D44 + D45)/10 to get result			
Vhydrop	*Highest:*	AU has 4 water regimes present	If D9.1 + D9.2 + D9.3 + D9.4 = 4, enter "1"	
	High:	AU has 3 water regimes present	If D9.1 + D9.2 + D9.3 + D9.4 = 3, enter "0.67"	
	Moderate:	AU has 2 water regimes present	If D9.1 + D9.2 + D9.3 + D9.4 = 2, enter "0.33"	
	Low:	AU has 1 water regimes present	If D9.1 + D9.2 + D9.3 + D9.4 = 1, enter "0"	
			Table continued on next page	
Vwaterdepth	*Highest:*	AU has 3 classes of depths	If D12.1 + D12.2 + D12.3 = 3, enter "1"	
	Moderate:	AU has 2 classes of depths	If D12.1 + D12.2 + D12.3 = 2, enter "0.67"	
	Low:	AU has 1 class of depths	If D12.1 + D12.2 + D12.3	

Variable	Description of Scaling		Score for Variable	Result
			= 1, enter “0.33”	
	Lowest:	AU has no surface inundation	If D12.1 + D12.2 + D12.3 = 0, enter “0”	
Vwintersp	*Highest:*	High interspersion	If D38 =3, enter “1”	
	Moderate:	Moderate interspersion	If D38 = 2, enter “0.67”	
	Low:	Low interspersion	If D38 = 1, enter “0.33”	
	Lowest:	No interspersion	If D38 = 0, enter “0”	
Vprichness	*Highest:*	Number of plant species > = 40	If calculation > = 1.0, enter “1”	
	Lowest:	AU has 2 or less plant species	If D19.1 + D19.2 < = 2, enter “0”	
	Calculation:	Scaled as # of species/40	Enter result of calculation	
	Calculate (D19.1 + D19.2)/40 to get result			
Vmature	*Highest:* *Lowest:*	AU has mature trees present AU has no mature trees present	If D22 = 1, enter “1” If D22 = 0, enter “0”	
Vedgestruc	*Highest:*	High structure at edge of AU	If D41 = 3, enter “1”	
	Moderate:	Moderate structure	If D41 = 2, enter “0.67”	
	Low:	Low structure	If D41 = 1, enter “0.33”	
	Lowest:	No structure	If D41 = 0, enter “0”	
			Total of Variable Scores:	
Reducer				
Vupcover	If clear cutting, high or low density residential, and urban land uses within 1 km are > = 60%.		If D3.3 + D3.4 + D3.5 + D3.6 > = 60, enter “0.9”	
	If critical land uses <60%		Enter “1”	
			Score for Reducer	
Index for General Habitat Suitability = Total for variables x reducer x 0.93rounded to nearest 1				
			FINAL RESULT:	

9.7.6 Qualitative Rating of Opportunity

The land-use patterns within the upland buffer and surrounding landscape influences the opportunity that an AU has to provide general habitat. Connectivity of AUs to other protected areas affects specific use of the habitat within the AU, in particular those species whose life history needs include a large range of landscape types (e.g. the larger predators, raptors, etc.). For some populations, the connectivity between wetland habitats may be crucial to the survivability of the population.

The opportunity that an AU has to provide habitat for a broad range of species should be judged by characterizing the landscape in which an AU is found. An AU may have many internal structural elements that indicate it provides good habitat. Its landscape position, however, may reduce the actual performance because it is not accessible to the populations that would use it.

Users must make a qualitative judgement on the opportunity the AU has in providing habitat for a broad range of species by considering the land uses in the contributing watershed, the condition of the AU's buffer, and its connection to other habitat areas. Two data on the field form can be used to help guide your judgement (D43 on corridors and D42 on buffers).

In general, the opportunity for an AU in the riverine impounding subclass to provide habitat is **"High"** if it has extensive natural buffers and forested or riparian corridors to other habitat areas. Other habitat areas may include undisturbed grasslands, open water, shrubs, or forested areas. The opportunity is **"Moderate"** if the AU has some connections to other habitat areas or less extensive undisturbed buffers. It is **"Low"** if the AU is surrounded by development and has no naturally vegetated corridors to other habitat areas.

The user must use their judgement in deciding whether the opportunity is low, moderate, or high, and document their decision on the data sheet.

9.8 Habitat Suitability for Invertebrates — Riverine Impounding Wetlands

Note: Please read the introduction to the assessment models (Chapter 2) before using these models. It describes several basic assumptions used in modeling that will help you better understand how to use and apply the methods.

9.8.1 Definition and Description of Function

Habitat Suitability for Invertebrates is defined as the wetland characteristics that help maintain a high number of invertebrate species in the wetland. The term invertebrates is here more narrowly defined as "macro-invertebrates" or free-living organisms readily seen with the naked eye (> 200 - 500 um). This includes the: Insecta (insects), Amphipoda (scuds, sideswimmers), Eubranchiopoda (fairy, tadpole, and clam shrimps) Decapoda (crayfishes, shrimps), Gastropoda (snails, limpets), Pelecypoda (clams, mussels), Hydracarina (water mites), Arachnida (spiders), and Annelida (worms and leeches).

The intent of the assessment is to identify those wetlands that provide habitat for the greatest number of invertebrate species within the regional subclass. Invertebrates are diverse, abundant, and essential components of freshwater aquatic ecosystems. Almost any AU will provide a habitat for some invertebrates. There is a distinct difference, however, between an AU that has a high abundance of one or two species and one that has a high richness of many different species. The important aspect of invertebrate populations that is being assessed is species richness. Wetlands with a high richness tend to be more important in maintaining the regional biodiversity of invertebrate populations and by providing genetic diversity that helps maintain ecosystem integrity.

Invertebrates have evolved unique adaptations to enable them to occupy most wetland habitats and trophic levels. Consequently, wetland invertebrates are pivotal components of complex food webs, significantly increasing the number of links with the rich diversity and abundance of their taxa. As filter feeders, shredders and scrapers, insects convert and assimilate microorganisms and vegetation into biomass providing significant production that then becomes available to secondary and tertiary consumers. Recent research focusing on aquatic invertebrates in wetlands indicates the importance of macro-invertebrates in energy and nutrient transfer within aquatic ecosystems (Rosenberg and Danks 1987). They furnish food for other invertebrates and comprise significant portions of the nutritional requirements of amphibians, water birds and small mammals. They are an especially important food source for young fish (e.g., salmonids and game fish). The trophic diversity and numerical abundance of insects, and especially Diptera (true flies), make these taxa one of the most important taxa in wetland environments.

In addition, macro-invertebrates are used as bioindicators of health in streams, lakes (Rosenberg and Resh 1996) and increasingly, in wetlands (Hicks 1996); as their taxa and numbers indicate conditions of water regime, soils, vegetation, eutrophication, and anthropogenic pollution.

9.8.2 Assessing this Function for Riverine Impounding Wetlands

The suitability of riverine impounding wetlands as habitat for a diverse assemblage of invertebrates is assessed by characterizing the complexity of the biologic and physical structures of the AU. The model is built on the assumption that almost any structure in the AU (i.e. channels, ponds, upland/AU edge, etc.) or plant association hosts a specialized invertebrate community. The operative assumption is that invertebrate richness increases as the number of structural characteristics do.

Certain conditions however, are considered to be detrimental to invertebrates and these are modeled as reducers of the performance. The presence of tannins is considered to reduce the performance of this function since many species are sensitive to organic acids present in tannins.

9.8.3 Model at a Glance

Riverine Impounding — Habitat Suitability for Invertebrates

Characteristics	Variables	Measures or Indicators
Number of habitat niches for invertebrates (applicable to all variables)	**Vpermflow**	Channels or streams in AU with permanently flowing water
	Vsubstrate	Types of surface substrates present
	Vwintersp	Characteristics of water interspersion - diagrams
	Vlwd	Categories of LWD present
	Vstrata	Number of strata present in any plant association
	Vvegintersp	Interspersion between vegetation classes -diagrams
	Vassemb	Number of plant assemblages
	Vhydrop	Number of water regimes
	Vaquastruc	Categories of different aquatic bed structures
Reducers		
	Vtannins	Qualitative estimate of presence/absence of tannins
	Index:	(Vpermflow + Vsubstrate + Vwintersp + Vlwd + Vstrata + Vvegintersp + Vassemb + Vhydrop + Vaquastruc) x (Vtannins) / Score from reference standard site

9.8.4 Description and Scaling of Variables

$V_{permflow}$ – Channels or streams are present in an AU and contain permanent flowing water.

Rationale: Permanent flowing water is a habitat feature that supports a unique assemblage of invertebrate species (Needham and Needham 1962, and Wiggins et al. 1980). Invertebrates found in flowing permanent channels are an important resource for many other aquatic species (Needham and Needham 1962). The presence of permanent flowing water is a characteristic that, when present, adds to the overall invertebrate richness in an AU.

Streams or channels with intermittent seasonal flow also have the potential for providing a special invertebrate habitat. They are not scaled in the model, however, because it was not possible to determine, in the field, if an intermittent stream or channel is maintained by seasonal flows or by high rainfall events. If an intermittent stream is a result of storm flows, the water does not remain long enough to provide a unique invertebrate habitat.

Indicators: No indicators are needed for this variable because the presence of permanent flow in a channel can be established directly in the summer during the dry season. Indicators for the presence of permanent channel flow in the winter, during the wet season, may be more difficult to establish. Users may have to rely on aerial photographs (usually taken in the summer) or other sources of information to determine if the flows in a channel are permanent.

Scaling: This is an "on/off" variable. An AU scores a [1] if permanent channel flow is present, and a [0] if it is not.

$V_{substrate}$ – The composition of surface layers present in the AU (litter, mineral, organic etc).

Rationale: Not much is known about invertebrate distributions in different substrates within a wetland. Data from rivers, streams, and lakes, however, show that the local invertebrate species have preferences for specific substrate (Dougherty and Morgan 1991, and Gorman and Karr 1978). In streams it is well known that Chironomid community composition is strongly affected by sediment characteristics (McGarrigle 1980, and Minshall 1984). The Assessment Teams assumed that a similar relationship between invertebrate populations and substrates is also found in wetlands. Thus, AUs with different substrates present will provide habitat for a broader group of invertebrate species than those with only one type. Moreover, those with organic matter will exhibit greater richness and abundance than those found in sand substrates.

Indicators: No indicators are needed to assess this variable. The number of different substrate types can be determined by direct field observations.

Scaling: AUs with five or more types of substrates of the eight identified (deciduous leaf litter, other plant litter, decomposed organic, exposed cobbles, exposed gravel, exposed sand, exposed silt, exposed clay) are scored a [1]. Those with fewer are scaled proportionally (# types/5). AUs with no soil surface exposed (e.g. sphagnum bog) are scored a [0].

$V_{wintersp}$ – The amount of interspersion present between vegetated portions of AU and permanent open water.

Rationale: The amount of interspersion between permanent open water and vegetation is another structural element of the AU that can add habitat complexity. Studies have shown that high invertebrate richness occurs where water was interspersed with stands of emergent vegetation (Voigts 1976).

Indicators: The interspersion in an AU is assessed using a series of diagrams that rates the interspersion as high, moderate, low, and none.

Scaling: Riverine impounding AUs with high interspersion are score a [1]; those with moderate are scored [0.67]; those with low = [0.33]; and those with no interspersion (i.e. no permanent open water) = [0].

V_{lwd} – The number of categories, based on size and level of decay, of fallen large woody debris (LWD) in permanent open water and on the vegetated surface of the AU. The categories are based on the Timber, Fish, and Wildlife rating criteria (Schuett-Hames et al. 1994).

Rationale: Downed woody material is an important structural element for invertebrate species. Decaying wood provides an important habitat for invertebrates (Maser et al. 1988). The Assessment Teams assumed that downed debris of different size and different classes of decay would provide habitat for a wide variety of invertebrates, especially those that decompose, feed and seek shelter in wood.

Indicators: Direct measures of the quantity and quality of decaying woody debris is not feasible for a rapid assessment method. Consequently, a descriptive matrix of different sizes and decay classes of woody debris was developed as an indicator for the variable. The matrix is based on the assessment procedure developed for the TFW watershed assessment methods.

Scaling: AUs with 10 (out of 24 possible) or more categories of LWD in open water and on the surface are scored a [1]. Those with less are scaled proportionally (# categories/10).

V_{strata} – The number of vegetation strata in any single plant assemblage. A plant assemblage can have up to 6 strata (layers: trees, high shrubs, low shrubs, woody vine, herbaceous, moss). To count as a stratum, however, the plants of that stratum have to have 20% cover in the association in which it is found.

Rationale: Different invertebrate taxa are found on different plant species (Cyr and Downing 1988). The vegetation strata are used as an indicator of plant species present in distinct groups that might have different ecological characteristics on which invertebrate taxa might be differentiated.

Indicators: No indicators are needed for this variable. The number of strata present in any single plant assemblage can be determined by direct field observations.

Scaling: AUs with 6 strata are scored a [1] for this variable. AUs with only one are scored a [0]. AUs with 2-5 strata are scaled proportionally as 0.2, 0.4, 0.6, and 0.8, respectively.

$V_{vegintersp}$ – The extent of interspersion between Cowardin vegetation classes.

Rationale: The extent of interspersion between vegetation class is a structural element of the plant community in an AU that reflects on habitat complexity. A higher diversity of plant communities (as characterized by Cowardin vegetation classes) is likely to support a higher diversity of macro-invertebrates (Chapman 1966, Dvorak and Best 1982, and Lodge 1985).

Indicators: The amount of interspersion between vegetation classes is assessed using diagrams found in the Washington State Rating System (WDOE 1993).

Scaling: AUs with more interspersion between vegetation classes score higher than those with fewer. The method has four categories of interspersion (none, low, moderate, high) and these are used as the basis for developing the scaled score. A high level of interspersion is scored a 1, a moderate = 0.67, a low = 0.33, and none = 0.

V_{assemb} – The number of distinct plant assemblages found within the AU.

Rationale: A mixture of plant assemblages exhibits a greater diversity and biomass of invertebrates than does a single one within an area (Andrews and Hasler 1943). For example, the standing crop of invertebrates varies considerably among different species of submerged aquatic macrophytes (Murkin and Batt 1987), and different epiphytic invertebrate taxa are found on different plant species (Cyr and Downing 1988.)

Indicators: No indicators are needed to assess this variable. The number of associations can be determined through field observations.

Scaling: Riverine impounding AUs with 9 or more plant assemblages are scored a [1]. AUs with fewer are scaled proportionally.

V_{hydrop} – The number of different water regimes present in the AU.

Rationale: Many lentic invertebrates have their life cycles keyed to different water regimes. A diversity of water regimes in an AU will, therefore, support more species than an AU with a less diverse water regimes. For example, some species are characteristics of permanent pools while other live in pools that are strictly temporary (Wiggins et al. 1980).

Indicators: The variable is assessed using four hydroperiod classes as descriptors. These are permanently flooded, seasonally flooded, saturated, occasionally flooded (see detailed description in Section 9.7.4).

Scaling: AUs with four hydroperiod classes are scored a [1]. Those with fewer are scored proportionally (3 classes = 0.67, 2 = 0.33, 1 = 0).

$V_{aquatstruc}$ – The number of different types of plant structures present in aquatic bed vegetation.

Rationale: Different types of aquatic bed vegetation provide different structure and consequently different niches for invertebrates (Wilcox and Meeker 1992). Thus, species richness increases as the structural diversity of aquatic bed vegetation increases.

Indicators: This variable is quantified using a diagram showing different types of structures found in aquatic bed vegetation.

Scaling: AUs with all three types of structure present score a [1]. Those with 2 score a [0.67]; those with 1 score [0.33]; and those with none score a [0].

$V_{tannins}$ **–** The concentration of tannins present in water. **This variable is used to indicate potential reductions in the level of performance for the function.**

Rationale: Tannins occur in undisturbed systems and may be limiting to invertebrates. For example, in Atlantic Canada isopods are presumed absent from ponds because they are humic (i.e. have tannins in them) (Walker et al. 1985).

Indicators: The presence of clear, brown, water in an AU (i.e. brown without any sediment or particulate matter) will be used as the indicator that tannins are present in sufficient concentrations to deter their use by invertebrates or to impair their growth. A more detailed description of how to characterize concentrations levels of tannins are described in Part 2.

Scaling: This is an "on/off" variable that results in a reduction in the overall index. AUs with tannins present have their index reduced by a factor of 0.7.

9.8.5 Calculation of Habitat Suitability

Riverine Impounding – Habitat Suitability for Invertebrates

Variable	Description of Scaling		Score for Variable	Result
Vpermflow	*Highest:*	AU has permanently flowing stream	If D4.1 = 1, enter "1"	
	Lowest:	AU has no permanent stream	If D4.1 = 0, enter "0"	
Vsubstrate	*Highest:*	5 categories of surface layers	If calculation is > = 1, enter "1"	
	Lowest	AU has no solid surface exposed	If calculation = 0, enter "0"	
	Calculation:	Scaling is based on the number of categories of surface layers present/5	Enter result of calculation	
	Calculate sum (D46.1 – D46.8)]/5 to get result			
Vwintersp	*Highest:*	High interspersion	If D38 = 3, enter "1"	
	Moderate:	Moderate interspersion	If D38 = 2, enter "0.67"	
	Low:	Low interspersion	If D38 = 1, enter "0.33"	
	Lowest:	no interspersion	If D38 = 0, enter "0"	
Vlwd	*Highest*	AU has at least 10 categories of different sizes and decomposition states of large woody debris	If calculation > = 1, enter "1"	
	Lowest:	No categories of LWD	If calculation = 0, enter "0"	
	Calculation:	Scaling based on the number of categories divided by 10	Enter result of calculation	
	Calculate (D44 + D45)/10 to get result			
Vstrata	*Highest:*	6 strata present	If D21 = 6, enter "1"	
	High:	5 strata present	If D21 = 5, enter "0.8"	
	Moderate:	4 strata present	If D21 = 4, enter "0.6"	
	Medium Low:	3 strata present	If D21 = 3, enter "0.4"	
	Low:	2 strata present	If D21 = 2, enter "0.2"	
	Lowest:	1 strata present	If D21 = 1, enter "0"	
Vvegintersp	*Highest:*	High interspersion between vegetation classes	If D39 = 3, enter "1"	
	Moderate:	Moderate interspersion	If D39 = 2, enter "0.67"	
	Low:	Low interspersion	If D39 = 1, enter "0.33"	
	Lowest:	No interspersion (1 class only)	If D39 = 0, enter "0"	

Table continued on next page

Variable	Description of Scaling		Score for Variable	Result
Vassemb	*Highest:*	AU has at least 9 plant assemblages	If calculation > = 1, enter "1"	
	Lowest:	AU has 1 plant assemblage	If D20 = 1, enter "0"	
	Calculation:	Scaling based on the number of assemblages normalized to 9	Enter result of calculation	
	Calculate (D20-1)/8 to get result			
Vhydrop	*Highest:*	AU has 4 water regimes present	If D9.1 + D9.2 + D9.3 + D9.4 = 4, enter "1"	
	Moderate:	AU has 3 water regimes present	If D9.1 + D9.2 + D9.3 + D9.4 = 3, enter "0.67"	
	Low:	AU has 2 water regimes present	If D9.1 + D9.2 + D9.3 + D9.4 = 2, enter "0.33"	
	Lowest:	AU has 1 water regime present	If D9.1 + D9.2 + D9.3 + D9.4 = 1, enter "0"	
Vaquastruc	*Highest*	AU has 3 structures of aquatic bed vegetation	If D25 = 3, enter "1"	
	High:	AU has 2 structures of aquatic bed vegetation	If D25 = 2, enter "0.67"	
	Moderate:	AU has 1 structures of aquatic bed vegetation	If D25 = 1, enter "0.33"	
	Lowest:	AU has 0 structures of aquatic bed vegetation	If D25 = 0, enter "0"	
			Total of Variable Scores:	
Reducer				
Vtannins	AU has tannins present		If D36 = 1, enter "0.7"	
	AU has no tannins present		If D36 = 0, enter "1"	
			Score for Reducer	
Index for Habitat Suitability for Invertebrates = Total for variables x reducer x 1.22 rounded to nearest 1				
			FINAL RESULT:	

9.9 Habitat Suitability for Amphibians — Riverine Impounding Wetlands

Note: Please read the introduction to the assessment models (Chapter 2) before using these models. It describes several basic assumptions used in modeling that will help you better understand how to use and apply the methods.

9.9.1 Definition and Description of Function

Habitat Suitability for Amphibians is defined as the wetland characteristics that contribute to the feeding, breeding, or refuge needs of amphibian species. Amphibians in the lowlands of western Washington are a vertebrate group that includes wetland-breeding frogs and toads (e.g., Order Anura, tailless amphibians except as larvae) and salamanders and newts (e.g., Order Caudata (Uradela) tailed amphibians). Their richness and abundance indicates they are extremely important in wetland trophic organization. Many native species only breed for a short time in wetlands and live in uplands as metamorphosed juveniles and adults (Richter 1998). Some species may be found in or close to wetlands throughout the year. Eggs and larvae of wetland breeding species, however, require free water for development.

Wetlands play an important role in the life cycles of amphibians by providing the quiet waters, shelter, and food sources needed for the early stages of development. The suitability of and AU as amphibian habitat is assessed by characterizing the conditions in a wetland that enable spawning, support the development of eggs and larvae, and provide protection and food for larvae and adults moving in and out of the wetland.

In general, the suitability of an AU as amphibian habitat increases as the number of appropriate habitat characteristics increase for all life stages. **The assessment model is focused on species richness and conditions that would support many different species, not on the importance of a wetland to a specific threatened or endangered species.**

If the wetland is a habitat type that appears to be critical to a specific species, another method is needed to better determine the habitat suitability of that wetland.

9.9.2 Assessing this Function for Riverine Impounding Wetlands

The suitability of an AU in the riverine impounding subclass as habitat for amphibians is modeled on the different types of physical and biologic characteristics present that have been shown to be important for the survival of amphibians.

Not all important wetland characteristics, however, could be assessed. For example, water level fluctuations are known to be important (Richter and Azous 1995, Azous and Richter 1995, and Richter 1997), but could not be characterized adequately in one site visit. Another variable known to be critical to amphibians in wetlands is the presence of corridors to other wetlands or upland habitats. The presence of relatively undisturbed migration routes between the AU and upland feeding and hibernation sites are an important habitat element for many amphibian species (Heusser 1968, Berven and Grudzien 1990, Beebee 1996). Moreover, dispersal routes from source populations are critical when populations are eliminated by stochastic processes including drought (Pounds and Crump 1994), disease (Bradford 1991), pollution (Richter pers. obs.), or when populations produce insufficient offspring to permanently occupy a site (Gill 1978a, b; and Sinsch 1992). Finally, amphibians within an AU benefit as members of a metapopulation extending across several wetlands by maintaining healthy populations that otherwise may go extinct from inbreeding depression (Sofgren 1991, 1994, and Pechmann and Wilbur 1994).

However, the information required to adequately assess the presence and suitability of corridors for amphibians proved to be too complex for a rapid assessment method. The data that can be collected from maps and aerial photos does not provide the resolution needed to adequately represent the needs of amphibians. Corridors need to be assessed on site, and the access to them may not be possible.

Two variables included (V_{phow} and $V_{upcover}$) reflect the potential for a reduction in the performance of this function. Acidic water will impair egg and larval development (Sadinski and Dunson 1992, and Rowe et al.

1992). Furthermore, natural habitats in the surrounding uplands are considered to be of paramount importance for maintaining viable amphibian populations (Semlitsch 1981, Kleeberger and Werner 1983, Bury and Corn 1988, and Dupuis et al. 1995). The absence of relatively undisturbed vegetation is modeled as a reduction in suitability of the wetland itself because it is a necessary condition if the wetland is to provide a suitable habitat for amphibians.

The Assessment Teams considered using the presence of fish and bullfrogs as a reducer of habitat suitability because both of these predators are known to prey on native amphibians. However, the presence of these species cannot always be determined during a single site visit. Users of the method are encouraged, though, to note the presence of either fish or bullfrogs in their report. If either predator is present, the index that is calculated by the assessment model may not reflect the actual habitat suitability of the AU.

9.9.3 Model at a Glance

Riverine Impounding — Habitat Suitability for Amphibians

Process	Variables	Measures or Indicators
Breeding, feeding, and refuge for amphibians (applicable to all variables)	**Vbuffcond**	Descriptive table of conditions in buffer
	Vsubstrate	Types of surface substrates present
	Vwintersp	Diagrams
	Vlwd	Categories of LWD present
	Vwater	% of AU with permanent water, or permanent water under FO or SS
	Vsubstruc	Categorization by dichotomous key
Reducers		
	Vphow	pH tabs, direct measurement
	Vupcover	Land uses within 1 km of wetland
	Index:	(Vbuffcond + Vsubstrate + Vwintersp + Vlwd + Vwater + Vsubstruc) x (Vphow or Vupcover) / Score from reference standard site

9.9.4 Description and Scaling of Variables

$V_{buffcond}$ – Condition of buffer within 100 m of the edge of the AU, as rated by extent of undisturbed areas.

Rationale: Conditions in the buffers of an AU are especially important in providing cover to amphibian females and to newly metamorphed animals. Female *R. aurora*, *A. gracile* (Richter pers. obs.) and *A. macrodactylum* (Beneski et. al. 1986, Leonard and Richter 1994) generally wait in buffers near wetlands until environmental and biological conditions are favorable to spawning. They then enter wetlands during one or a few nights to spawn, thereafter quickly retreating to cover of buffers. Metamorphs of most species also benefit from wetland buffers. They are important to the tiger salamander (*A. tigrinum*) seeking shelter in rodent burrows during the first days following emigration from natal ponds (Loredo et al. 1996). Metamorphs of *P. regilla*, *B. boreas R. aurora* and *T. granulosa* may spend several weeks in buffers prior to dispersing upland if soil and vegetation is dry beyond the buffer (Richter pers. obs.). Vulnerable metamorphs and juveniles have moisture, cover, and abundant invertebrate prey within forested wetland buffers.

Indicators: This variable is determined using a buffer categorization developed from the Washington State Rating System (WDOE 1993) (Part 2).

Scaling: Buffer categories are scaled as follows: category 5 = 1, category 4 = 0.8, category 3 = 0.6, category 2 = 0.4, category 1 = 0.2, and category 0 = 0.

$V_{substrate}$ – The composition and types of surface layers present in the AU (litter, mineral, organic etc).

Rationale: Organic matter and leaf litter are important to larval amphibians as substrates for the zooplankton, phytoplankton, algae, and invertebrates that provide their food. Moreover, structural diversity in the form of leaf litter and woody debris provides shelter from weather and cover from predation. Different types of substrates provide niches for different invertebrate communities and thereby increase the richness of potential food sources.

Indicators: No indicators are needed to assess this variable. The substrate types can be determined by direct field observations.

Scaling: Scaling is based on the total number of different types of substrate present in the AU. Organic substrates, however, are given more importance (by a factor of two) because of their additional role as shelter. AUs with 3 categories of organic litter and 2 categories of inorganic surface types are scored a 1. Those with fewer are scaled proportionally (see Calculation Table 9.9.5).

***V**_{wintersp}* – The extent of interspersion present between vegetated portions of the AU and permanent open water.

Rationale: Most species of amphibians generally avoid both open water and densely vegetated sites, instead selecting habitats with an interspersion of both features (Strijbosch 1979, Ildos and Ancona 1994, Richter and Roughgarden in preparation, and Richter pers. obs.). Quantitative comparisons of vegetation cover surrounding *A. gracile* eggs suggest dense (95-100%) and light (0-5 %) cover is avoided (Richter and Roughgarden in preparation). Research findings suggest that for most species an interspersion between open water and vegetation is selected for oviposition. A 25-75 or 75-25 ratio of open water to vegetation may, therefore, be considered optimum for spawning.

Indicators: The extent of interspersion in a wetland is characterized by using a series of diagrams that rate interspersion into high, medium and low. Diagrams are based on those used in Wetland Evaluation Technique (Adamus et al. 1987, p.56) and in the Western Washington Rating Systems (WDOE 1993).

Scaling: Riverine impounding AUs with high interspersion are score a [1]; those with moderate are scored [0.67]; those with low = [0.33], and those with no interspersion (i.e. no permanent open water) = [0].

$\boldsymbol{V_{lwd}}$ – The number of categories, based on size and level of decay, of fallen large woody debris (LWD) in the permanent open water and on the vegetated surface of the AU. The categories are based on the Timber, Fish, and Wildlife rating criteria (Schuett-Hames et al. 1994).

Rationale: There is no clear documentation of the quantity and type of large woody debris that is of benefit to amphibians in wetlands. However, tadpoles of western toads (*Bufo boreas*) frequently rest attached to large floating logs (Richter pers. obs.). Large woody debris in water most likely is important also as cover for larvae and adults, and as attachment sites for the algae and invertebrates that provide food.

Indicators: Direct measures of the quantity and quality of decaying woody debris is not feasible for a rapid assessment method. A descriptive matrix of different sizes and decay classes of woody debris was developed as an indicator for the variable. The matrix is based on the assessment procedure developed for the TFW watershed assessment methods.

Scaling: AUs with 10 (out of 24 possible) or more categories of LWD in open water and on the surface are scored a [1]. Those with less are scaled proportionally (# categories/10).

V_{water} – The percent of the AU with permanent open water, aquatic bed vegetation, and areas of permanent standing water under a canopy of trees or shrubs.

Rationale: The extent of water without emergent vegetation is used as a surrogate for water level fluctuation. The assumption is that AUs with some open or standing water have lower water level fluctuations during the breeding season. Attempts were made to characterize water level fluctuations during the field calibration, but it was impossible to estimate the fluctuations that actually occur during the breeding season. The presence of open water is used as an indicator that water is present during the breeding season and that fluctuations will be lower than if no permanent water is present.

Most species of amphibians in temperate climates minimize exposure of eggs to fluctuating depths and temperatures by both spawning in mid-depth water and by submerging eggs below the surface (Richter 1997).

Amphibian egg development also depends on permanent or partial submergence, and, therefore, optimum habitat conditions are those where water levels are stabilized from spawning through hatching. In most Puget Sound species this is from mid-December through mid-May. Although mean water level fluctuations exceeding 20 cm have been correlated to decreased amphibian richness in wetlands (Azous and Richter 1995) experiments suggest that extended drops of more than 7 cm from oviposition through hatching may harm *A. gracile*. Moreover, eggs of *A. macrodactylum* and *P. regilla* spawned in shallow water are harmed by stranding and desiccation on shore if water level fluctuations are severe.

Indicators: The percent of the AU that is in permanent open water or in aquatic bed vegetation can be estimated during the site visit. The presence of permanent standing water under a canopy of trees or shrubs is characterized only as present/absent.

Scaling:

	Score	
Highest	AU has at least 50% open water (Permanent Open water + aquatic bed)	1
High	AU has 10- 49% open water	0.8
Moderate	AU has no open water, but has permanent water under SS or FO or EM	0.5
Low	AU has 1-9% open water	0.2
Lowest	AU has **no** open water, or permanent water under SS or FO or EM	0

***V**$_{substruc}$* – A characterization of plant structures present under the water surface.

Rationale: Northwest caudates attach their eggs directly to vegetation within the water column (Slater 1936, Anderson 1967, Richter 1997 and references therein). Anurans anchor eggs to vegetation either below or near the surface (e.g. *R. aurora*, *B. boreas*) or occasionally spawn free-floating eggs (*R. pretiosa*; Licht 1969).

Experimental evidence suggests that vegetation structure, particularly plant shape and stem diameter are the oviposition criteria most important to caudates. Wetland surveys and controlled field studies of several northwest salamanders confirm that distinct stem widths are preferred by ovipositing caudates (Richter 1997). From these surveys and studies it can be inferred that species of submerged vegetation are unimportant for oviposition. Rather, the important factor is the size and structure of submerged vegetation.

Underwater structure is also important as a source of diversity in the food source. It provides a substrate for invertebrates and algae.

Indicators: This variable is determined by using a descriptive key outlining different categories of underwater structures for egg laying. This key is located in Part 2. The key rates the structures on a scale of 0-4.

Scaling: AUs with a rating of 4 in the key are scored a 1; those with a rating of 3 are scored a 0.75; rating of 2 = 0.5; rating of 1 = 0.25; and rating of 0 = 0.

***V**$_{phow}$* **– T**he pH of open surface water in the AU. This variable is used to indicate potential reductions in the level of performance for the function.

Rationale: Acidic waters impair egg and larval development of Pacific Northwest amphibians. Hence they are generally absent from wetlands with a pH in its surface waters of 4.5 or less (Richter unpub. data).

Indicators: No indicators are needed. The pH of surface water can be measured directly using pH strips.

Scaling: AUs with a pH of 4.5 or less are assigned an index of [0] for the function. Those with a pH >4.5 but < 5.5 have their index reduced by a factor of 0.5. AUs with a pH of 5.5 or greater do not have their score reduced.

***V**$_{upcover}$* – The types of land uses within 1 km of the estimated AU edge. This variable is used to indicate potential reductions in the level of performance for the function

Rationale: Wetlands that provide full range of biological processes of consequence to amphibians are located in relatively undeveloped areas (Schueler 1994, and Richter and Azous 1995). Development increases water discharges, current velocities, and water level fluctuations in the AU. These environmental conditions diminish suitable amphibian breeding, feeding, and rearing habitat. Moreover, wetland invertebrates and plants are also known to decrease in richness and abundance with

greater water level fluctuations and concomitant pollution loads (Schueler 1994, Ludwa 1994, Azous and Richter 1995, and Hicks 1995) further reducing the quality of amphibian habitat in the AU.
Indicators: No indicators are needed to assess this variable. The amount and type of land uses within 1 km of the wetland can be established from aerial photographs or site visits.
Scaling: AUs with at least 60% of their surrounding land in urban or high density residential use have their index for the function reduced by a factor of 0.5. Those with at least 50% in clear-cut are also reduced by 0.5. AUs with at least 30% of their surrounding areas in any active land use (residential, urban, clear-cut, or agriculture) have their index reduced by a factor of 0.8.

9.9.5 Calculation of Habitat Suitability

Riverine Impounding – Habitat Suitability for Amphibians

Variable	Description of Scaling		Score for Variable	Result
Vbuffcond	*Highest:*	Buffer category of 5	If D42 = 5, enter “1”	
	High:	Buffer category of 4	If D42 = 4, enter “0.8”	
	Moderate:	Buffer category of 3	If D42 = 3, enter “0.6”	
	Medium Low:	Buffer category of 2	If D42 = 2, enter “0.4”	
	Low:	Buffer category of 1	If D42 = 1, enter “0.2”	
	Lowest:	Buffer category of 0	If D42 = 0, enter “0”	
Vsubstrate	*Highest:*	3 categories of organic litter + 2 inorganic surface layers	If D46.1 + D46.2 + D46.3 =3 and sum (D46.4 to D46.8) > = 2, enter “1”	
	Lowest:	AU has no ground surface exposed	If sum (D46.1 - D46.8) = 0, enter “0”	
	Calculation:	Scaling is based on the number of categories of surface layers present; with organic surface layers weighted by a factor of two.	Enter result of calculation	
	If sum (D46.4 - D46.8) > = 2 calculate [(D46.1 + D46.2 + D46.3) x 2 + 1]/8; if sum (D46.4 - D46.8) < = 1 calculate [(D46.1 + D46.2 + D46.3) x 2 + sum (D46.4 - D46.8)]/8			
Vwintersp	*Highest:*	High interspersion between land and water	If D38 = 3, enter “1”	
	Moderate:	Moderate interspersion	If D38 = 2, enter “0.67”	
	Low:	Low interspersion	If D38 = 1, enter “0.33”	
	Lowest:	No interspersion	If D38 = 0, enter “0”	
Vlwd	*Highest:*	AU has at least 10 size categories and decomposition states of LWD	If calculation > = 1, enter “1”	
	Lowest:	No categories of LWD	If calculation = 0, enter “0”	
	Calculation:	Scaling based on the number of categories divided by 10	Enter result of calculation	
	Calculate (D44 + D45)/10 to get result			
Vwater	*Highest:*	AU has at least 50% exposed water (POW +AB)	If D8.3 + D14.6 > = 50, enter “1”	
	High:	AU has 10- 49% exposed water	If D8.3 + D14.6 > = 10 and < 50, enter “0.8”	
	Moderate:	AU has no exposed water, but has permanent water in SS, FO or EM	If D8.3 + D14.6 = 0 and D9.1 = 1, enter “0.5”	
	Low:	AU has 1-9% exposed water	If D8.3 + D14.6 > = 1 and < 10, enter “0.2”	
	Lowest:	AU has no water, or permanent water under SS or FO or EM	If D8.3 + D14.6 = 0 and D9.1 = 0, enter “0”	

Table continued on next page

Variable	Description of Scaling		Score for Variable	Result
Vsubstruc	*Highest:*	Score of 4 on underwater structures for egg laying	If D35 = 4, enter “1”	
	High:	Score of 3 on underwater structures for egg laying	If D35 = 3, enter “0.75”	
	Moderate:	Score of 2 on underwater structures for egg laying	If D35 = 2, enter “0.5”	
	Low:	Score of 1 on underwater structures for egg laying	If D35 = 1, enter “0.25”	
	Lowest:	Score of 0 on underwater structures for egg laying	If D35 = 0, enter “0”	
			Total of Variable Scores:	
Reducer				
Vphow	pH of standing water < 4.5		If D26.2 < = 4.5, enter “0”	
	pH of standing water >4.5 and < 5.5		If D26.2 > 4.5 and < 5.5, enter “0.5”	
	pH of standing water > = 5.5		If D26.2 > = 5.5, enter “0.8”	
Vupcover	AU has > + 60% urban or high density residential land use; OR > = 50% clear cut within 1 km		If D3.4 + D3.5 > = 60 **OR** D3.3 > = 50, enter “0.5”	
	AU has as least 30% of area within 1 km in active land uses		If sum (D3.2-D3.6) > = 30, enter “0.8”	
	AU has less than 30% of area within 1 km in active land uses		If sum (D3.2-D3.6) < 30, enter “1”	
			Score for Reducer (Choose Lowest Value)	
Index for Amphibians = Total for variables x reducer x 1.75 rounded to nearest 1				
			FINAL RESULT:	

9.10 Habitat Suitability for Anadromous Fish — Riverine Impounding Wetlands

Note: Please read the introduction to the assessment models (Chapter 2) before using these models. It describes several basic assumptions used in modeling that will help you better understand how to use and apply the methods.

9.10.1 Definition and Description of Function

Habitat Suitability for Anadromous Fish is defined as the environmental characteristics that contribute to the feeding, breeding, or refuge needs of anadromous fish. Many wetlands provide cover, depth, surface area, and other attributes necessary for the over-wintering life history phase of coho salmon (*Oncorhynchus kisutch*). Other anadromous fish noted in off channel wetlands include cutthroat trout (*Oncorhynchus clarki*) steelhead (*Oncorhynchus mykiss*) (Peterson 1982). Because the distribution and habitat requirements of salmonids and non-salmonids overlap, it is assumed that an AU meeting the habitat requirements of salmonids will also meet the requirements of non-salmonid anadromous fish (Johnson and Stypula 1993).

The models assess general habitat suitability, not the importance of a wetland to a specific threatened or endangered species, or to a specific regionally important species assemblage. The function is modeled based on the structural elements, physical components, and the characteristics of the AU that are considered to be important elements of habitat for anadromous fish. In general, the suitability of an AU as habitat for anadromous fish is assumed to improve as the number of beneficial habitat characteristics increase.

If the AU is a habitat type that appears to be critical to a specific species, another method is needed to better determine the habitat suitability of that AU (e.g. USFWS Habitat Evaluation Procedures (HEP) USFWS 1980).

9.10.2 Assessing this Function for Riverine Impounding Wetlands

The suitability of a riverine impounding AU to provide habitat for anadromous fish is modeled by combining variables that represent feeding, refuge, and over-wintering conditions for the fish. The elements of an AU that are considered to provide these conditions are interspersion between land and water, adequate water depths, permanent open water, the presence of different types of cover, and adequate food in the form of invertebrates. The model contains one variable that is associated with a reduction in the effectiveness with which AUs provide anadromous fish habitat. V_{bogs} is used to represent acidic conditions and low productivity that decrease the suitability of an AU to provide habitat for anadromous fish. The general characteristics considered suitable for anadromous fish were first developed from the work of Bjornn and Resier (1979) and supplemented by other references as described below for the individual variables.

The model for riverine impounding wetlands does not have a variable to reflect an absolute requirement for permanent water, that would at first, seem to be a necessary pre-requisite for fish habitat. The presence of permanent open water is considered important but not necessary. The Assessment Teams judged that AUs would provide habitat features important to anadromous fish even in the absence of any permanent water because seasonal flooding in the winter and early spring provides both forage and refuge during a critical time in the life cycle some of anadromous fish.

Habitat Suitability for Anadromous Fish is one of the two habitat functions for which it may be possible to also judge opportunity as part of a rapid assessment method. The Assessment Teams decided that an AU does have the opportunity to provide habitat for anadromous fish if its surface water outlet has a direct connection that is passable by fish to a stream with anadromous fish in it. Information on locations used by anadromous fish is more readily available than for other wildlife. The Washington State Department of Fish and Wildlife maintains an extensive database of streams used by anadromous fish, and this can be used as a guide in rating the opportunity. Local sources may also be contacted for information on the presence of anadromous fish.

9.10.3 Model at a Glance

Riverine Impounding — Habitat Suitability for Anadromous Fish

Characteristics	Variables	Measures or Indicators
Feeding and refuge for anadromous fish (applies to all variables)	**Vwintersp**	Diagrams of interspersion between land and water
	Vwaterdepth	Number of water depth categories present
	Vcover	Categories of refuge present in water
	Vpow	% of AU in permanent open water
	Sinverts	Score for function "Habitat Suitability for Invertebrates"
Reducers		
Acidic bogs	**Vbogs**	% area of sphagnum bogs in AU
	Index:	(Vwintersp + Vwaterdepth + 2 x Vcover + Vpow + Sinverts) x Vbogs / Score for reference standard site

$$\text{Index} = \frac{(\text{Vwintersp} + \text{Vwaterdepth} + 2 \times \text{Vcover} + \text{Vpow} + \text{Sinverts}) \times \text{Vbogs}}{\text{Score for reference standard site}}$$

9.10.4 Description and Scaling of Variables

$V_{wintersp}$ – The amount of interspersion present between vegetated portions of an AU and open water.

Rationale: Interspersion between land and water permits aquatic organisms to enter and leave the AU via permanent or ephemeral surface channels, overbank flow (Brinson et.al. 1995). These organisms provide food for anadromous fish. In addition, such interspersion provides refuge from predation for overwintering salmonids by increasing the area of protected shallow waters with vegetated banks. Contact zones between open water and vegetation provide protection from wind, waves, and predators, and may provide natural territorial boundaries (Golet and Larson 1974).

Indicators: The interspersion in an AU is assessed using a series of diagrams that rates the interspersion as high, moderate, low, and none.

Scaling: Riverine impounding AUs with high interspersion are scored a [1]; those with moderate are scored [0.67]; those with low = [0.33], and those with no interspersion (i.e. no permanent open water) = [0].

$V_{waterdepth}$ – A categorization of different depths of water present in an AU.

Rationale: Anadromous fish need a certain water depth for optimum habitat conditions. Narver (1978) observed juvenile coho moving into areas with water depth over 45 cm and lower velocities (15 cm/s) when temperatures declines below 7^{o}C. Beaver ponds and off-channel areas with similar depths have also been found to provide habitat (Reeves et al. 1989). Survival and growth of over-wintering fish may be maximized in systems that contain both shallow pools and deeper ones (Peterson 1982).

Indicators: The variable is characterized using a condensed form of the depth categories first developed for WET habitat assessments (Adamus et al. 1987). These are 0-20 cm, 20-100 cm, and > 100 cm.

Scaling: AUs with three depth categories present are scored a [1]. Those with the two shallower ones are scored a [0.5]; those with 0-20 cm of water are scored a [0.1]. AUs with no permanent or seasonal inundation are scored a [0]. If the water depth is greater than 100 cm but the AU does not have enough shallow water to meet the size requirements (0.1 ha or 10%, whichever is the smaller) it is scored a [0.7].

V_{cover} – Structures in the AU that provide cover in and over water. This variable is assessed based on three structural elements: 1) vegetation that overhangs permanent water; 2) undercut banks; and 3) large woody debris in permanent water. **This variable is considered to be a critical habitat component and is weighted by a factor of 2 relative to the other variables.**

Rationale: Overhanging vegetation and undercut banks provide both temperature control and protection from predation. McMahon (1983) reported the need for streamside vegetation for shading. Small coho juveniles tend to be harassed, chased and nipped by larger juveniles unless they stay near the bottom, obscured by rocks or logs (Groot and Margolis 1994). Cover for salmonids can be provided by overhanging vegetation, undercut banks, submerged vegetation, submerged objects such s logs and rocks, floating debris, deep water, turbulence and turbidity (Giger 1973). Large woody debris plays an important role in Pacific Northwest streams, creating and enhancing fish habitat in streams of all sizes (Bisson et al. 1987).

When juvenile salmonids move into depressional wetlands they will need the same type of cover as found in streams. The Assessment Teams judged that the types of cover found in streams also are necessary in wetlands if the habitat is to be judged as suitable.

Indicators: The presence of overhanging vegetation and undercut banks is characterized during the field visit based on presence/absence of certain characteristics as described in Part 2. Direct measures of the quantity and quality of decaying woody debris is not feasible for a rapid assessment method. A descriptive matrix of different sizes and decay levels of woody debris was developed as an indicator for the variable. The matrix is based on the assessment procedure developed for the TFW watershed assessment methods.

Scaling: AUs with either overhanging vegetation or undercut banks, and at least 6 categories of large woody debris in permanent open water are scored a [1]. AUs with fewer characteristics are scored proportionally, with each type of cover having equal weight (see Calculation Table 9.10.5). AUs with no types of cover are scored a [0].

V_{pow} – The percent of the AU that is covered by permanent open water.

Rationale: AUs that have permanent surface water present provide habitat the entire year rather than just during the wet season. As mentioned in the introduction, the model for riverine impounding wetlands does not have a variable to reflect an absolute requirement for permanent water that would, at first, seem to be a necessary pre-requisite for fish habitat. AUs with permanent open water, however, provide better habitat than those flooded only seasonally.

Indicators: The variable is assessed by estimating the relative % of the AU with permanent open water (Part 2).

Scaling: AUs that have 30% or more permanent open water are scored a [1]. Those with less are scored proportionally (%pow/30).

$S_{inverts}$ – The index from the function "Habitat Suitability for Invertebrates."

Rationale: Invertebrates in wetlands are a major food source for overwintering and young anadromous fish. The index for the function is an indication of the potential food sources available to the salmonids. Higher richness is indicative of a broader range of food sources and well as a more balanced availability of such food. The salmonids would not have to rely on only one or two species that could potentially be subject to large fluctuations.

Indicators: No indicators are needed for this variable since it is a index for another function.

Scaling: The index is already scaled from 0-10 and re-normalized to a range of 0 - 1.

V_{bogs} – The percent area of AU that is covered by a Sphagnum bog (defined as areas where Sphagnum mosses represent more than 30% cover of the ground). **This is a variable of reduced performance.**

Rationale: The presence of a bog is an indication that the area has a low rate of primary production, regardless of its other characteristics (Mitch and Gosselink 1993). It also may contain acidic waters and high concentration of tannins. The Assessment Teams judged that the presence of bogs were a good indicator that the AU is not as suitable a habitat for anadromous fish.

Indicators: No indicators are needed for this variable since the % area of a bog can be determined directly.

Scaling: The variable is used to reduce the performance index for the function. AU' s that are more than 25% bog have their index for this function reduced by 0.5.

9.10.5 Calculation of Habitat Suitability

Riverine Impounding – Habitat Suitability for Anadromous Fish

Variable	Description of Scaling		Score for Variable	Result
Vwintersp	*Highest:*	Interspersion is high	If D38 = 3, enter "1"	
	Moderate:	Interspersion is moderate	If D38 = 2, enter "0.67"	
	Low:	Interspersion is low	If D38 = 1, enter "0.33"	
	Lowest:	No interspersion	If D38 = 0, enter "0"	
Vwaterdepth	*Highest:*	All water depth categories present	If D12.1 = 1 and D12.2 = 1 and D12.3 = 1, enter "1"	
	Medium High:	Only water depths > 100 cm present	If D12.3 = 1 and D12.1 + D12.2 = 0, enter "0.7"	
	Moderate:	Depths between 0-20 cm and 20-100 cm present	If D12.1 =1 and D12.2 = 1, enter "0.5"	
	Low:	Depths between 0-20 cm present	If D12.1 = 1, enter "0.1"	
	Lowest:	No surface water present	If all D10 = 0, enter "0"	
Vcover	*Highest:*	AU scored 1 for overhanging veg. and has 6 or more categories of woody debris in permanent water	If D32 = 1 and D34 = 1 and D45 > = 6, enter "2"	
	Lowest:	No categories of cover present	If D32 + D34 + D45 = 0, enter "0"	
	Calculation:	Scaled as overhanging vegetation + # of categories of woody debris/6	Enter result of calculation	
	If D45 < 4 calculate D32 + D34 + (D45/6) to get result; if D45 > 6 calculate D32 + D34 + 1 to get result			
Vpow	*Highest:*	AU has > = 30% perm. open water	If D8.3 > = 30, enter "1"	
	Lowest:	No permanent open water in AU	If D8.3 = 0, enter "0"	
	Calculation:	Scaled as % open water/30	Enter result of calculation	
	If D8.3 < 30 calculate D8.3/30 to get result			
Sinverts	*Score is scaled*	Index for Habitat Suitability for Invertebrates	Index of function/10	
			Total of Variable Scores:	
Reducer				
Vbogs	Sphagnum bog component of AU is > = 25%		If D23.1 + D23.2 + D23.3 > = 1, enter "0.5"	
	Sphagnum bog component of AU is < 25%		If D23.1 + D23.2 + D23.3 = 0, enter "1"	
			Score for Reducer	
Index for Habitat Suitability for Anadromous Fish = Total for variables x reducer x 1.67 rounded to nearest 1				
			FINAL RESULT:	

9.10.6 Qualitative Rating of Opportunity

The Assessment Teams decided that an AU does have the opportunity to provide habitat for anadromous fish if its surface water outlet has a direct connection that is passable by fish to a stream with anadromous fish in it. Information on locations used by anadromous fish is more readily available than for other wildlife. The

Washington State Department of Fish and Wildlife maintains an extensive database of streams used by anadromous fish, and this can be used as a guide in rating the opportunity. Local sources may also be contacted for information on the presence of anadromous fish.

If the AU has an unobstructed passage to a stream or river with anadromous fish it should be rated as having a **"High"** opportunity to provide habitat. If there is no passage, or the passage is obstructed, the opportunity is **"Low"**.

9.11 Habitat Suitability for Resident Fish — Riverine Impounding Wetlands

Note: Please read the introduction to the assessment models (Chapter 2) before using these models. It describes several basic assumptions used in modeling that will help you better understand how to use and apply the methods.

9.11.1 Definition and Description of Function

Habitat Suitability for Resident Fish is defined as the wetland characteristics that contribute to the feeding, breeding, or refuge needs of resident native fish.

This function is modeled based on the structural elements, physical components, and other characteristics of an AU that are considered to be important elements of habitat for resident native fish. In general, the suitability of an AU as habitat for resident fish is assumed to improve as the number of beneficial habitat characteristics increase. **The assessment models are focused on general habitat suitability, not on the importance of an AU to a specific threatened or endangered species or to a specific regionally important species assemblage.**

The model for riverine impounding wetlands does not have a variable to reflect the requirement for permanent water, that would at first, seem to be a necessary pre-requisite for fish habitat. The presence of permanent open water is considered important but not necessary. The Assessment Teams judged that wetlands without permanent water can provide habitat for resident fish during periods when the wetland is connected to other bodies of water by surface water. When this occurs, (often during seasonal flooding in the winter and early spring) the wetland may provide both forage and refuge for fish.

9.11.2 Assessing this Function for Riverine Impounding Wetlands

The suitability of AUs in the riverine impounding subclass as habitat for resident fish is modeled on specific physical and biologic characteristics of an AU. These characteristics include the interspersion between vegetation and water, the amount of cover for fish, the characteristics of the substrate, the depth water, and the presence of a permanently flowing stream. In addition, the models include the score for the “invertebrate function” that represents a food source for fish.

9.11.3 Model at a Glance

Riverine Impounding — Habitat Suitability for Resident Fish

Characteristics	Variables	Measures or Indicators
Feeding and breeding and refuge for resident native fish (applies to all variables)	**Vwintersp**	Diagrams of interspersion between land and water
	Vwaterdepth	Number of water depth categories present
	Vcover	Categories of refuge present in water
	Vpow	% of AU in permanent open water
	Vpermflow	Presence/absence of permanent flow in channel
	Vsubstrate	Types of surface substrates present
	Sinverts	Index for function "Habitat Suitability for Invertebrates"
	Index:	(Vwintersp + Vwaterdepth + Vcover + Vpow + Vpermflow + Vsubstrate + Sinverts) / Score from reference standard site

9.11.4 Description and Scaling of Variables

$V_{wintersp}$ – The amount of interspersion present between vegetated portions of the AU and open water.

Rationale: Interspersion between land and water permits aquatic organisms to enter and leave the wetland via permanent or ephemeral surface channels, overbank flow, or unconfined hyporheic gravel aquifers (Brinson et.al. 1995). These provide food for resident fish as well as anadromous fish. In addition, such interspersion provides refuge from predation by increasing the area of protected shallow waters with vegetated banks. Contact zones between open water and vegetation provide protection from wind, waves, and predators, and may provide natural territorial boundaries (Golet and Larson 1974).

Indicators: The interspersion in an AU is assessed using a series of diagrams that rates the interspersion as high, moderate, low, and none.

Scaling: Riverine impounding AUs with high interspersion are scored a [1]; those with moderate are scored [0.67]; those with low = [0.33], and those with no interspersion (i.e. no permanent open water) = [0].

$V_{waterdepth}$ – The varying depths of water present in an AU.

Rationale: Resident fish need a range of water depths for different parts of their life cycles. Shallow waters provide refuge for young fish, while the deeper waters provide refuge for the larger adults. Varying water depths also provide different potential food sources since they are host to different populations of plants and invertebrates.

Indicators: The variable is characterized using a condensed form of the depth classes first developed for WET habitat assessments (Adamus et al. 1987). These are 0-20 cm, 20-100 cm, and > 100 cm.

Scaling: AUs with all three depth classes present are scored a [1]. Those with the two shallower ones are scored a [0.5]; those with 0-20 cm of water are scored a [0.1]. AUs with no permanent or seasonal inundation are scored a [0]. In some cases an AU may have steep sides. If the water depth is greater than 100 cm but the AU does not have enough shallow water to meet the size requirements (0.1 ha or 10%, whichever is the smaller) it is scored a [0.7].

V_{cover} – Structures in the AU that provide cover in and over water. This variable is assessed based on three structural elements: 1) vegetation that overhangs permanent water; 2) undercut banks; and 3) large woody debris in permanent water.

Rationale: Refuge from predators is an important habitat feature for maintaining successful fish populations, and wetlands that provide such refuge have a higher potential of performing than those that do not. Overhanging vegetation and undercut banks provide both temperature control and protection from predation. Large woody debris plays an important role in the Pacific Northwest, creating and enhancing fish habitat (Bisson et al. 1987).

Indicators: The presence of overhanging vegetation and undercut banks is characterized during the field visit based on presence/absence of certain characteristics as described in Part 2. Direct measures of the quantity and quality of decaying woody debris is not feasible for a rapid assessment method. A descriptive matrix of different sizes and decay levels of woody debris was developed as an indicator for the variable. The matrix is based on the assessment procedure developed for the TFW watershed assessment methods.

Scaling: AUs with both overhanging vegetation and undercut banks, and at least 6 categories of large woody debris are scored a [1]. AUs with fewer characteristics are scored proportionally, with each type of cover having a different weight (see Calculation Table 9.11.5). Large woody debris is weighted by a factor of 3 and undercut banks by a factor of 2 relative to overhanging vegetation. AUs with no types of cover are scored a [0].

V_{pow} – The percent of the AU that is covered by permanent open water.

Rationale: Ponded surface water is needed for fish. Wetlands that have permanent surface water present provide habitat the entire year rather than just during the wet season, thereby increasing the suitability of the AU as habitat.

Indicators: The variable is assessed by estimating the relative % of the AU that has permanent open water (Part 2).

Scaling: AUs that have 30% or more permanent open water are scored a [1]. Those with less are scored proportionally (%pow/30).

$V_{permflow}$ – There are channels or streams present in the wetland that have permanently flowing water.

Rationale: This variable is included for the function because flowing water is an important characteristic for cottids and dace in western Washington (Mongillo pers. comm.). These species tend to be found usually in flowing water.

Indicators: No indicators are needed for this variable in the summer because the presence of permanent flow in a channel can be established directly during the dry season. Indicators for the presence of permanent channel flow in the winter during the wet season, however, may be more difficult to establish. Users may have to rely on aerial photographs (usually taken in the summer) or other sources of information to determine if the flows in a channel are permanent.

Scaling: This is an “on/off” variable. An AU scores a [1] if permanent channel flow is present, and a [0] if it is not.

$V_{substrate}$ – The composition of surface layers present in the AU (litter, mineral, organic etc).

Rationale: Different types of surface layers present in a wetland provide different habitats for resident fish species in western Washington (Mongillo pers. comm.).

Indicators: No indicators are necessary to assess this variable. The types of substrate present can be determined during the site visit.

Scaling: Since each type of substrate provides a different habitat feature for resident fish, the scaling is based on the number of types of organic substrate present and cobbles and gravel. Wetlands with 4, or more, of the 5 types of substrate present score a [1]. Those with fewer are scaled proportionally (# types/4). AUs with no exposed substrate score a [0].

$S_{inverts}$ – The index for the function “Habitat Suitability for Invertebrates.”

Rationale: Invertebrates are a major food source for both resident and anadromous fish. The index for the function is an indication of the potential food sources available to resident fish. Higher richness is indicative of a broader range of food sources and well as a more balanced availability of such food. Resident fish would not have to rely on only one or two species that could potentially be subject to large fluctuations.

Indicators: No indicators are needed for this variable since it is a index for another function.

Scaling: The index is already scaled from 0-10, and is re-normalized to a range of 0 - 1.

9.11.5 Calculation of Habitat Suitability

Riverine Impounding – Habitat Suitability for Resident Fish

Variable	Description of Scaling		Score for Variable	Result
Vwintersp	*Highest:*	Interspersion is high	If D38 = 3, enter "1"	
	Moderate:	Interspersion is moderate	If D38 =2, enter "0.67"	
	Low:	Interspersion is low	If D38 =1, enter "0.33"	
	Lowest:	No interspersion	If D38 =0, enter "0"	
Vwaterdepth	*Highest:*	All water depth categories present	If D12.1 + D12.2 + D12.3 = 3, enter "1"	
	High:	Water depths between 0-100 cm present	If D12.1 = 1 and D12.2 = 1, enter "0.8"	
	Medium High:	Water depths > 100 cm present	If D12.3 = 1 and D12.1 + D12.2 = 0, enter "0.7"	
	Low:	Depths between 0-20 cm present	If D12.1 = 1, enter "0.1"	
	Lowest:	No surface water present	If all D10 = 0, enter "0"	
Vcover	*Highest*	AU has overhanging veg., undercut banks, and 6 or more categories. of woody debris in perm. water	If D32 + D34 = 2 and D45 > = 6, enter "1"	
	Lowest:	No categories of cover present	If D32 + D34 + D45 = 0, enter "0"	
	Calculation:	Scaled as the number of categories with weights of: 1 for overhang, and 3 for LWD normalized to 4	Enter result of calculation	
	If D45 > = 6 calculate (D32 + 2 x D34 + 3)/6; if D45 < 6 calculate [D32 + 2 x D34 + (D45/6 x 3)]/6			
Vpow	*Highest:*	AU has > = 30% perm. open water	If D8.3 > = 30, enter "1"	
	Lowest:	AU has no permanent open water	If D8.3 = 0, enter "0"	
	Calculation:	Scaled as % open water/30	Enter result of calculation	
	If D8.3 < 30 calculate D8.3/30 to get result			
Vpermflow	*Highest*	Perm. flowing channel or stream	If D4.1 = 1, enter "1"	
	Lowest	AU has no permanent channel	If D4.1 = 0, enter "0"	
Vsubstrate	*Highest:*	AU has at least 4 types of substrate	If calculation > = 1, enter "1"	
	Lowest:	AU has no exposed substrate	If calculation > = 0, enter "0"	
	Calculation:	Scaled as # of gravel, cobbles and organic substrate types / 4	Enter result of calculation	
	Calculate [sum (D46.1 - D46.5)]/4 to get result			
Sinverts	*Score is scaled*	Index for Habitat Suitability for Invertebrates	Index of function/10	
			Total of Variable Scores:	
	Index for Habitat Suitability for Resident Fish = Total for variables x 1.52 rounded to nearest 1			
			FINAL RESULT:	

9.12 Habitat Suitability for Wetland-associated Birds — Riverine Impounding Wetlands

Note: Please read the introduction to the assessment models (Chapter 2) before using these models. It describes several basic assumptions used in modeling that will help you better understand how to use and apply the methods.

9.12.1 Definition and Description of Function

Habitat Suitability for Wetland-associated Birds is defined as the environmental characteristics in a wetland that provide habitats or life resources for species of wetland-associated birds. Wetland-associated bird species are those that depend on aspects of the wetland ecosystem for some part of their life needs: food, shelter, breeding, resting. The guilds of Wetland-associated birds used as the basis for building the assessment model includes waterfowl, shorebirds, and herons.

In general, the suitability of an AU as bird habitat increases as the number of appropriate habitat characteristics increase. Another assumption used in developing the model is that AUs that provide habitat for the greater number of wetland dependent bird species are scored higher than those that have fewer. **The assessment models are focused on species richness, not on the importance of a wetland to a specific threatened or endangered species or to a specific regionally important guild.**

If the AU is a habitat type that appears to be critical to a specific species, another method is needed in order to determine the habitat suitability of that AU (e.g. USFWS Habitat Evaluation Procedures (HEP), USFWS 1981).

9.12.2 Assessing this Function for Riverine Impounding Wetlands

The suitability of wetlands in the riverine impounding subclass as habitat for wetland-associated birds is modeled based on the plant structure, physical components, and the condition of the buffers around the AU. In addition, the models include the indices for other habitat functions that represent prey of birds: namely the habitat suitability index for amphibians, invertebrates, and fish.

AUs that have a closed canopy are judged to have a reduced level of performance because access for waterfowl is limited. The Assessment Teams also judged that the presence of invasive or non-native birds may reduce the suitability of an AU. A variable for this factor was not included in the model because reproducible data on invasive or non-native birds could not be collected during one site visit.

Size is not used as a variable in the equation although it is often cited as an important characteristic of wetlands that provide bird habitat (Richter and Azous in preparation). The question of size is a vexing one, and no satisfactory size thresholds have been identified in the literature that would define the importance of a small versus a large wetland as habitat specific to only wetland-associated birds. Size, however, is incorporated indirectly in the scaling of some of the other variables used. Thus, it is implicit that an AU with a diverse structure is large—small AUs simply cannot contain the same number of different structural elements as large ones.

9.12.3 Model at a Glance

Riverine Impounding — Habitat Suitability for Wetland-associated Birds

Characteristics	Variables	Measures or Indicators
Feeding, breeding, and refuge for wetland – associated birds (applies to all variables)	**Vbuffcond**	Descriptive table of conditions in buffer

	Vsnags	Categories of snags present
	Vvegintersp	Characteristics of interspersion between vegetation classes - diagrams
	Vedgestruc	Characteristics of AU edge
	Vspechab	Presence of special habitat features
	Vpow	% permanent open water
	Sinverts	Index for function – Habitat Suitability for Invertebrates
	Samphib	Index for function – Habitat Suitability for Amphibians
	Sfish	Index for higher of two: Anadromous or Resident Fish
Reducers		
Canopy closed	**V%closure**	% canopy closure over AU
	Index:	(Vbuffcond + Vsnags + Vvegintersp + Vspechab + Vpow + Vedgestruc + Sinverts +Samphib + Sfish) x (V%closure) / Score from reference standard site

9.12.4 Description and Scaling of Variables

V$_{buffcond}$ – Condition of buffer within 100 m of the edge of the AU, as rated by extent of undisturbed areas.

Rationale: The condition of the AU buffer affects the ability of the AU to provide appropriate habitat for some guilds (Zeigler 1992). Trees and shrubs provide screening for birds using the AU, as well as providing additional habitat in the buffer itself (Johnson and Jones 1977, Milligan 1985, and Zeigler 1992). The Assessment Teams judged, however, that good buffers are more important in small AUs because many wetland-associated birds can use the interior of the larger units without being disturbed.

Indicators: This variable is assessed using the buffer categorization described in the data sheets (Part 2).

Scaling: If the AU is greater than 6 ha, the variable is scored a [1]. Smaller AUs with buffers that are vegetated with relatively undisturbed vegetation of at least 100 m around 95% of the AU (buffer category #5) are scored a [1]. The categories between 0-5 are scaled proportionally as 0, 0.2,0.4, 0.6, and 0.8 respectively. **The size threshold is included so large wetlands are not penalized for having poor buffers**.

V$_{snags}$ **–** The number of different categories of snags, based on decomposition states, found in the AU.

Rationale: Snags are a source of cavities and perches for wetland-associated birds. Several species of birds utilize already existing cavities for nesting and/or refuge locations. The presence of cavities in standing trees can indicate the relative age or maturity of the trees within the AU, and therefore the structural complexity present. Dead wood attracts invertebrates and other organisms of decay, which in turn provide a food source for many species of birds (Davis et al. 1983).

Indicators: The number and size of cavities in an AU cannot be measured directly because they may be difficult to count and measure. Eight different categories of snags representing different levels of decay are used as the indicator for the different potential sizes of cavities. It is assumed that cavities will form or be excavated if dead branches or trunks are present.

Scaling: If a riverine impounding AU has 6 or more of the 8 categories of snags present it scored a [1]. Fewer categories are scaled as proportional to 6 (i.e. # of categories/6).

V$_{vegintersp}$ – The relative interspersion between Cowardin vegetation classes (Cowardin et al. 1979).

Rationale: Vegetation interspersion is the relative position of plant types to one another. As an example, an AU may have an emergent marsh of cattails; a nearby shrub/swamp of willows; and an adjacent area of alder swamp. This AU contains three Cowardin classes - emergent, shrub, and forest.

For some bird species, this is irrelevant, as many species are single habitat type users. Other species, though, may require several habitat types to being close proximity to aid their movements from one type to another (Gibbs 1991, Hunter 1996).

Indicators: The amount of interspersion between vegetation classes is assessed using diagrams developed from those found in the Washington State Rating System (WDOE 1993).

Scaling: AUs with more interspersion between vegetation classes score higher than those with fewer. The method has four categories of interspersion (none, low, moderate, high) and these are used as the basis for developing a scaled score. A high level of interspersion is scored a 1, a moderate a 0.67, a low = 0.33, and none = 0.

V $V_{edgestruc}$ – The vertical structure and linear characteristics of the AU edge.

Rationale: The configuration (e.g., length of shoreline in relation to area) and differences in vegetation strata along the edge of the AU are important habitat characteristics for many species of wetland-associated birds. Additional habitat exists within vegetated lobes and scalloped edges of AUs with a differences in edge strata and the shape of the AU edge.

For example, a simple AU may be a nearly circular pond with a fringing emergent marsh composed of cattails, which adjoin immediately to an upland of grazed pasture. The edge of the AU in this case is characterized as having low structural complexity (lack of shrubs and trees), and low linear complexity (as the edge is nearly circular, with no embayments or peninsulas). In contrast, a more complex AU may adjoin with an upland composed of trees and shrubs, adding to the structural complexity, and may be irregular along the edge, with many twists and turns, resulting in enclosed bays and jutting peninsulas. Further, embayments and peninsulas provide “micro-habitats” for certain species that require hiding cover, or “feel” more secure within a more enclosed system (USDI 1978, Verner et al. 1986, and WDOE 1993).

Indicators: The structure of the AU/upland edge is assessed by using a descriptive key that groups the edges and vertical structure along the edge into “high” structural complexity, medium, low, and none.

Scaling: AUs with a high structural complexity at the edge are scored a [1]; moderate = 0.67, low = 0.33, and none = 0.

$V_{spechab}$ **–** Special habitat features that are needed or used by aquatic birds. Five different habitat characteristics are combined in one variable. These are:

1) the AU is within 8 km (5 mi) of a brackish or salt water estuary;
2) the AU is within 1.6 km (1 mi) of a lake larger than 8 ha (20 acres);
3) the AU is within 5 km (3 mi) or an open field greater than 16 ha (40 acres);
4) the AU has upland islands of at leas 10 square meters (108 square feet) surrounded by open water (the island should have enough vegetation to provide cover for nesting aquatic birds); and
5) the AU has unvegetated mudflats.

Rationale: The suitability of an AU as habitat for aquatic birds is increased by a number of special conditions. Specifically, the proximity of an AU to open water or large fields increases its utility to migrant and wintering waterfowl. If there is strong connectivity between relatively undisturbed aquatic areas the suitability as habitat is higher (Gibbs et al. 1991, Verner et al. 1986). In addition, islands surrounded by open water provide a protected nesting area for ducks if they have adequate cover. Mudflats are an important feeding area for migrating birds.

Indicators: No indicators are needed for this variable because the presence of the special habitat features can be determined on site, from maps, or aerial photos.

Scaling: If an AU has 2 or more of the 5 habitat features it is scored a [1]. AUs with one habitat feature score a [0.5] for the variable, and those with none score a [0].

V_{pow} – The percent area of the AU that is covered by permanent open water.

Rationale: Permanent open water provides refuge for many species of waterfowl. The presence of open water allows for the establishment of aquatic vegetation beds, which also provides food for different species of waterfowl.

In addition, open water of varying depths provides greater diversity of foraging habitat for a greater variety of water birds (USDI 1978). Shallow water areas (less than 20 cm deep) provide habitat for rails and teal. The permanent open water should be present throughout the breeding season for maximum functional benefit (Eddelman et al. 1988). To simplify the models the Assessment Teams decided that the variable “permanent open water” is more appropriate than trying to determine whether the water is open during the breeding season. It is understood that some AUs may have open water during the breeding season, but then completely dry up in the late summer. It is too difficult however to establish the presence of open water only during the breeding season.

The extent of the permanent open water required for different scaled scores is based on an educated guess by the Assessment Team, reflecting the need to provide a rapid method. Areas of open water that are smaller than .1 hectare (1/4 acre), or less than 10% of an AU (if it is < 1 hectare), are difficult to determine from aerial photos.

Indicators: The extent of permanent open water in a AU can be easily determined during the dry summer months and no indicator is needed. There is a problem, however, in establishing the size during the wet season when the AU is flooded to its seasonal levels. The indicators that have been suggested to establish the extent of permanent inundation are the edge of emergent vegetation in the deeper portions of a AU, or the presence of aquatic bed vegetation such as *Nuphar spp*.

Scaling: AUs with 30%, or more, of their area covered in permanent open water are scored a [1] for this variable. AUs with a smaller area are scaled proportionally (%open water/30).

$S_{inverts}$ – The habitat suitability index from the Invertebrate function.

Rationale: The index is used to represent the availability of invertebrates as prey for birds.

Indicators: No indicators are needed. The variable is an index from another function.

Scaling: The index is already scaled between 0 –10, and is re-normalized to a range of 0 -1.

S_{amphib} – Habitat suitability index for the Amphibian function.

Rationale: The index is used to represent the availability of amphibians as prey for birds.

Indicators: No indicators are needed. The variable is an index from another function.

Scaling: The index is scaled between 0 –1, and is re-normalized to a range of 0 – 1.

S_{fish} – Habitat suitability index for the "fish" function. The assessment methods have two functions to characterize habitat suitability for fish (anadromous and resident). The higher of the two scores is used in this model.

Rationale: The index is used to represent the availability of fish as prey for birds.

Indicators: No indicators are needed. The variable is an index from another function.

Scaling: The index is scaled between 0 –10, and is re-normalized to a range of 0 -1.

$V_{canopyclos}$ **–** The percent of the AU with a canopy closure of woody vegetation in the AU that is >75%. **This variable reduces the suitability of an AU as bird habitat as it discourages access by certain wetland-associated birds such as herons.**

Rationale: A full canopy can limit access to any water in the AU because birds have difficulty flying in and out. This may be best illustrated by great blue herons, which will be reluctant to fly down to a body of water if the tree canopy above is totally closed, because rapid escape may be difficult or impossible (USDI 1978).

Indicators: No indicators are needed for this variable because the percent canopy closure can be estimated during the site visit or from aerial photos.

Scaling: AUs with a canopy closure greater than 70% have their suitability index reduced by a factor of 0.7.

9.12.5 Calculation of Habitat Suitability

Riverine Impounding – Habitat Suitability for Wetland-associated Birds

Variable	Description of Scaling		Score for Variable	Result
Vbuffcond	*Highest:*	Buffer category of 5 or AU > 6ha	If D1 > = 6 or If D42 = 5, enter "1"	
	High:	Buffer category of 4	If D1 <6 and if D42 = 4, enter "0.8"	
	Moderate:	Buffer category of 3	If D1 <6 and if D42 =3, enter "0.6"	
	Medium Low:	Buffer category of 2	If D1 <6 and if D42 = 2, enter "0.4"	
	Low:	Buffer category of 1	If D1 <6 and if D42 = 1, enter "0.2"	
	Lowest:	Buffer category of 0	If D1 <6 and if D42 = 0, enter "0"	
Vsnags	*Highest:*	At least 6 categories of snags	If D31 > = 6, enter "1"	
	Lowest	No snags present	If D31 = 0, enter "0"	
	Calculation:	Scaled as # categories/6	Enter result of calculation	
	If D31 < 6 calculate D31/6 to get result			
Vvegintersp	*Highest:*	High interspersion	If D39 = 3, enter "1"	
	Moderate:	Moderate interspersion	If D39 = 2, enter "0.67"	
	Low:	Low interspersion	If D39 = 1, enter "0.33"	
	Lowest:	No interspersion (1 class only)	If D39 = 0, enter "0"	
Vedgestruc	*Highest:*	High structure at edge of AU	If D41 = 3, enter "1"	
	Moderate:	Moderate structure	If D41 = 2, enter "0.67"	
	Low:	Low structure	If D41 = 1, enter "0.33"	
	Lowest:	No structure	If D41 = 0, enter "0"	
Vspechab	*High:*	AU has > = 2 of 5 special habitat features	If sum (D8.5 + D27 + D28 + D29 + D33) > = 2, enter "1"	
	Moderate:	AU has 1 of 5 special habitat features	If sum (D8.5 + D27 + D28 + D29 + D33) = 1, enter "0.5"	
	Lowest:	AU has no special habitat features	If sum (D8.5 + D27 + D28 + D29 + D33) = 0, enter "0"	
Vpow	*Highest:*	AU has > = 30% perm. open water	If D8.3 > = 30, enter "1"	
	Lowest:	AU has no permanent open water	If D8.3 = 0, enter "0"	
	Calculation:	Scaled as % open water/30	Enter result of calculation	
	If D8.3 < 30 calculate D8.3/30 to get result.			
Sinverts	*Scaled score:*	Index for Invertebrates	Use (index of function)/10	
Samphib	*Scaled score:*	Index for Amphibians	Use (index of function)/10	
Sfish	*Scaled score:*	Index for Fish	Higher of 2 indices: (Anadromous Fish/10) or (Resident Fish/10)	
			Total for Variables	
Reducer				
V%closure	Canopy closure > 70%		If D17 > 70, enter "0.7"	
	Canopy closure < = 70%		If D17 < = 70, enter "1"	
			Score for Reducer	
Index for Habitat Suitability for Wetland-associated Birds = Total for variables x reducer x 1.14 rounded to nearest 1				
			FINAL RESULT:	

9.13 Habitat Suitability for Wetland-associated Mammals — Riverine Impounding Wetlands

Note: Please read the introduction to the assessment models (Chapter 2) before using these models. It describes several basic assumptions used in modeling that will help you better understand how to use and apply the methods.

9.13.1 Definition and Description of Function

Habitat Suitability for Wetland-associated Mammals is defined as wetland features and characteristics that support life requirements of four aquatic or semi-aquatic mammals. Mammalian species whose habitat requirements were modeled are the beaver (*Castor canadensis*), muskrat (*Ondatra zibethicus*), river otter (*Lutra canadensis*), and mink (*Mustela vison*).

The model for this function is based on general habitat requirements for each of the four wetland-associated mammals. The model reflects the suitability of an AU to support mammal richness rather than individual species abundance. Habitat considerations in the model are restricted to the condition of the wetland buffer, and characteristics that can be found within the AU itself. It is assumed that wetlands that provide habitat for all four of the aquatic mammal species function more effectively than ones that meets the habitat needs of fewer species.

Wetlands that are found within urban or residential areas are modeled as having a reduced level of performance. Adjacent areas that are developed provide an avenue for humans, cats, dogs, and other domestic animals to harass mammal populations.

The SWTC and Assessment Teams decided to focus the model specifically on the aquatic fur-bearing mammals because these are wetland dependent species that are important to society, and they represent different types of mammals that use wetlands. Many terrestrial mammals will use wetlands, if they are available, to meet some of their life maintenance requirements. These species, however, do not need wetlands. It would have been too difficult to develop a mammal model that incorporates habitat features for all mammals using wetlands. Such models would have had to incorporate too much information about the surroundings uplands and expanded the scope of the assessment methods to the extent that they would no longer be considered "rapid."

If the AU is a habitat type that appears to be critical to a specific species, another method is needed in order to determine the habitat suitability of that AU (e.g. USFWS Habitat Evaluation Procedures (HEP), USFWS 1981).

9.13.2 Assessing this Function for Riverine Impounding Wetlands

The suitability of wetlands in the riverine impounding subclass as mammal habitat is modeled by buffer conditions, water depths, presence of open water, connectivity of the site to other suitable habitat, interspersion of vegetation and open water, and the presence of characteristics important to each species modeled. The index for the fish habitat function is added as a variable to reflect the importance fish have in the diet of otters and, to a lesser degree, mink. Reduction in suitability is modeled based on the percentage of the surrounding landscape, within 1 km, that is developed ($V_{upcover}$).

9.13.3 Model at a Glance
Riverine Impounding — Habitat Suitability for Wetland-associated Mammals

Characteristics	Variables	Measures or Indicators
Breeding, feeding, and refuge for beaver, mink, otter, and muskrat (applies to all variables)	**Vbuffcond**	Descriptive table of buffer conditions
	Vwaterdepth	Number of water depth categories present
	Vcorridor	Categorical rating of corridor
	Vbrowse	Area of woody vegetation for beaver
	Vemergent2	At least .25 ha of emergent vegetation
	Vwintersp2	Diagrams of interspersion if AU
	Vow	% of AU in open water and aquatic bed
	Vbank	Banks present of fine material
	Vpermflow	AU has channel with permanent flowing water
	Sfish	Index for higher of two: Anadromous or Resident Fish
Reducers		
Development	**Vupcover**	Land uses within 1 km of AU

Index: $\dfrac{\text{(Vbuffcond + Vwaterdepth + Vcorridor + Vbrowse + Vemergent2 + Vwintersp2 + Vow + Vbank + Vpermflow + Sfish) x (Vupcover)}}{\text{Score from reference standard site}}$

9.13.4 Description and Scaling of Variables

$V_{buffcond}$ – Land-use patterns within 100 m of the edge of the AU.

Rationale: A relatively undisturbed buffer serves to minimize disturbance (Burgess 1978, Allen and Hoffman 1984), provide habitat for prey species and food sources for mammals (Brenner 1962, Dunstone 1978, Allen 1983), cover from predators (Melquist et al. 1981), and den sites for resting and reproduction for wetland-associated mammals (Allen 1983). Both live standing vegetation and dead decaying plant material are important components of good buffer conditions.

Indicators: This variable is assessed using the buffer categorization described in the data sheets in Part 2.

Scaling: AUs with buffers that are vegetated with relatively undisturbed plant communities of at least 100 m around 95% of the AU (buffer category #5) are scaled a [1]. The categories between 0-5 are scaled proportionally as 0, 0.2,0.4, 0.6, and 0.8 respectively.

$V_{waterdepth}$ – The varying depths of water present in a AU during the dry season.

Rationale: Adequate water depth is an essential criterion for beaver and muskrat. These aquatic rodents are vulnerable to predation when water depths are shallow. Declines in water level expose lodge or bank burrow entrances to predators. Further, permanent water conditions increase the potential for a resident fish population which serves as a stable food supply for mink and river otters.

Indicators: The variable is scored using a condensed form of the depth classes developed for WET habitat assessments (Adamus et al. 1987). These are 0-20 cm, 20-100 cm, and >100 cm.

Scaling: AUs with water depths greater than 1 m are scored a [1] for this variable. Those with water depths between 1-100 cm are scored a [0.5]; those with depths between 1-20 cm are scored a [0.3]; and those with water depths less than 1 cm are scored a [0].

$V_{corridor}$ – The type of vegetated connections present between the AU and other nearby habitat areas.

Rationale: This variable characterizes the connection of the AU to other relatively undisturbed areas capable of providing mammal habitat. Adolescent mammals born and raised within an AU use natural riparian corridors to move from their natal area to unoccupied habitat. Riparian corridors that have relatively undisturbed vegetation cover ensure that dispersing animals are capable of reaching and populating or repopulating unoccupied habitat. Further, mink and river otter have a number of core activity areas within a larger home range. A loss of adequate travel corridors between core activity areas has potential to restrict or eliminate mammal use if the area of suitable habitat drops below required levels.

Indicators: This variable is determined using a modified corridor rating system developed in the Washington State Rating System (WDOE 1993.) Corridors are rated on a scale of 0-3 (Part 2).

Scaling: AUs rating a 3 for their corridor connections are scored a [1] for this variable. Those with a rating of 2 are scored [0.67]; those with a rating of 1 are scored [0.33]; and those with a rating of 0 are scored [0].

V_{browse} – This variable characterizes the presence of woody deciduous plants that beaver prefer as a primary food source.

Rationale: Woody deciduous species commonly used by beaver include willow *(Salix spp.)*, aspen *(Populus tremuloides*) cottonwood *(Populus spp.)* (Denney 1952.) Trees and shrubs closest to the AU edge are generally used first (Brenner 1962). In a California study, 90% of all cutting of woody material was within 100 feet of the AU edge (Hall 1970). Red alder *(Alnus rubra)* is also a common food source in the lowlands of western Washington.

Indicators: This variable is determined by estimating the amount of alder, willow, aspen and cottonwood within the AU, and/or within a 100 m buffer around the AU.

Scaling: This is an "on/off" variable. AUs with more than 1 hectare (2.5 acres) of willow, aspen, or cottonwood in them or in their buffer will score a [1]. AUs with less will score a [0]. The size is threshold based on the data collected during the field calibrations and the judgements of the Assessment Teams regarding suitable beaver habitat. Literature for areas outside the Pacific Northwest suggests that much larger areas are needed to sustain a beaver family (Denney 1952), but the Assessment Teams judged these numbers were not appropriate.

$V_{emergent2}$ – Emergent plants are present in the AU that cover more than 0.4 ha (1 acre).

Rationale: Muskrat and beaver use persistent emergent cover for security and feeding (Errington 1963, Jenkins 1981). Muskrats also use this vegetation as material for lodge construction (Wilner et al. 1980). Allen (1983) believes that beaver prefer herbaceous vegetation over woody vegetation during all seasons, if available.

Indicators: This variable is estimated using the Cowardin vegetation class "emergent" as an indicator of the amount of persistent emergent vegetation used by the mammals.

Scaling: This is an "on/off" variable. AUs with an area of emergent vegetation that is larger than 0.4 ha score a [1] for the variable. AUs that do not meet this criterion score a [0]. AUs need to have a minimum of 0.4 ha in emergent cover to score for this variable. Muskrats appear to prefer the greatest of aerial coverage in emergent cover. The size threshold is based on the judgement of the Assessment Teams. 0.4 ha is considered to be the minimum necessary to maintain a family of muskrats or beaver.

$V_{wintersp2}$ – The amount of interspersion present between vegetated areas of the AU and permanent open water if the AU is at least 0.4 ha (1 acre) in size.

Rationale: For muskrat and beaver, interspersion of vegetation and open water equates to the ease of access to feeding and lodge building sites, and food availability for mink and otter. A diverse mixture of open water and emergent vegetation distributed in a mosaic fashion is assumed to support the largest numbers of muskrats. Beaver colony territories are distinct and non-overlapping (Bradt 1938). High interspersion rates which optimize prey levels (i.e., muskrats, water birds, and fish) optimize food abundance and availability for mink and river otter. King (1983) reported that habitat quality influences the distribution, density, and reliability of prey, which, in turn, directly affect mink population density and distribution. Food abundance and availability appeared to have the greatest influence on habitat use by river otter in Idaho (Melquist and Hornocker 1983). Classic muskrat studies by Dozier (1953) and Errington (1937) indicate that optimum muskrat habitat has approximately 66 to 80% of the AU in emergent vegetation with the remainder in open water.

A size threshold is included in this variable because the Assessment Teams assumed that very small AUs are not suitable habitat even if they have good interspersion between vegetated parts and the open water.

Indicators: The interspersion in an AU is assessed using a series of diagrams that rates the interspersion as high, moderate, low, and none. The size of the AU is estimated from maps or aerial photos.

Scaling: If an AU is less than 0.4 ha in size it is scored a [0] for this variable. If it is larger, then AUs with high interspersion are scored a [1]; those with moderate are scored [0.67]; those with low = [0.33], and those with no interspersion (i.e. no permanent open water) = [0].

V_{ow} **–** The percentage of the AU that has open water. This includes the areas of permanent open water and that can be classified as "aquatic bed" vegetation using the Cowardin (1979) classification.

Rationale: For muskrat and beaver open water is needed for feeding and lodge building sites, and access to food for mink and otter. Beaver colony territories are distinct and non-overlapping (Bradt 1938). Classic muskrat studies by Dozier (1953) and Errington (1963) indicate that optimum muskrat habitat has approximately 66 to 80% of the AU in emergent vegetation with the remainder in open water. Beaver need an unknown, but lesser proportion, of open water.

A size threshold of 0.1 ha is included in this variable because the Assessment Teams assumed that very small areas of open water are not suitable for the mammals.

Indicators: The size of the area that is in permanent open water and aquatic bed vegetation is estimated during the site visit and from maps or aerial photos.

Scaling: If the area of permanent open water and aquatic bed vegetation is less than 0.1 ha (1/4 acre) the variable is scored a [0]. If it is larger, then AUs with at least 30% of their area in open water are scored a [1]; those with less are scored proportionally (% open water/30).

V_{bank} **–** This variable identifies the presence of slope and soil conditions that are suitable for muskrat, otter, and beaver bank burrows.

Rationale: When studying bank burrowing muskrats, Earhart (1969) found that a minimum bank slope of 10° was required before burrows were consistently observed regardless of soil type. Gilfillan (1947) considered 30° or more slope as optimum conditions for muskrat bank burrows when the bank height exceeds 0.5 meters (1.6 feet). Muskrat and beaver are capable of constructing bank burrows in a wide range of soil conditions. Muskrat studies by Errington (1937) and Earhart (1969) note that clay soils provide the most suitable substrate for burrow excavation, but even soils with high sand content may provide suitable burrowing sites if dense vegetation exists (Errington 1937). Beaver are capable of constructing lodges against a bank or over the entrance of a bank burrow (Allen 1983) and appear to have less specific slope and soil type limitations for bank burrows.

Indicators: No indicators are needed to assess this variable. The presence of banks can be determined during the site visit. A steep bank that can be used for denning must be: 1) > 30 degrees 2) more than 0.6 m (2 ft.) high (vertical), 3) of fine material such as sand, silt, or clay.

Scaling: This is an "on/off" variable. AUs meeting the criteria for banks are scored a [1] for the variable. Those with no banks are scored a [0].

$V_{permflow}$ **–** There are channels or streams present in the AU that have permanently flowing water.

Rationale: This variable is included in the model because flowing water is an important characteristic for otters. In addition, the presence of permanent flowing water is an indicator that a surface water connections exists that will facilitate the dispersal of wetland-associated mammals living in the AU.

Indicators: No indicators are needed for this variable in the summer because the presence of flow in a channel can be established directly in the summer during the dry season. Indicators for the presence of permanent channel flow in the winter, during the wet season, may be more difficult to establish. Users may have to rely on aerial photographs (usually taken in the summer) or other sources of information to determine if the flows in a channel are permanent.

Scaling: This is an "on/off" variable. An AU scores a [1] if permanent channel flow is present, and a [0] if it is not.

S_{fish} – Habitat suitability index from the "fish" function. The assessment methods have two functions to characterize habitat suitability for fish (anadromous and resident). The higher of the two scores is used in this model.

Rationale: This variable is specific to river otter and to a lesser extent for mink. Melquist and Hornocker (1983) found fish to be the most important prey of otters studied over a four year period. Annually, fish occurring in 93-100% of the 1,902 scats analyzed this Idaho study. Mink exhibit considerable variation in their diet, according to season, prey availability, and habitat type (Wise et al. 1981, Linscombe et al. 1982, and Smith and McDaniel 1982). In an Idaho study, fish occurred more frequently (59%) in the diet of mink than any other prey category. However, Eberhardt and Sargeant (1977) reported that mink in North Dakota AUs, which do not support fish, preyed heavily on birds and mammals.

Indicators: No indicators are needed. The variable is an index from another function.

Scaling: The index is scaled between 0 – 10, and is re-normalized to a range of 0 –1. The higher of the two scores for fish (resident or anadromous) is used to characterize the potential for fish as a food source.

$V_{upcover}$ – The types of land uses within 1 km of the estimated AU edge. This variable is used to indicate potential reductions in the level of performance for the function.

Rationale: Human alteration to the AU buffer has direct impacts to the AUs habitat suitability for mammals. These alterations also include the associated negative impacts from harassment by humans and domestic animals. Loss or alteration of the natural areas around an AU has direct adverse impacts to feeding, loafing, and breeding habitat for mink, river otter, and muskrat and beaver. These mammals are vulnerable to harassment and predation by domestic pets (Errington 1937, Slough and Sadleir 1977, Burgess 1978, and Melquist and Hornocker 1983). This variable is in contrast to $V_{buffcond}$, which gives a positive value rating to buffers in good condition. Two variables were needed to represent upland conditions because $V_{buffcond}$ does not address the issue of disturbances to mammals from specific adjacent land uses.

Indicators: No indicators are needed to assess this variable. The amount and type of land uses within 1 km of the AU can be established from aerial photographs or site visits.

Scaling: AUs with at least 15% of their surrounding land in urban land uses, or at least 20% high density residential use, or at least 40% low density residential land use, have their index for the function reduced by a factor of 0.7.

9.13.5 Calculation of Habitat Suitability

Riverine Impounding – Habitat Suitability for Wetland-associated Mammals

Variable	Description of Scaling		Score for Variable	Result
Vbuffcond	*Highest:*	Buffer category of 5	If D42 = 5, enter “1”	
	High:	Buffer category of 4	If D42 = 4, enter “0.8”	
	Moderate:	Buffer category of 3	If D42 = 3, enter “0.6”	
	Medium Low:	Buffer category of 2	If D42 = 2, enter “0.4”	
	Low:	Buffer category of 1	If D42 = 1, enter “0.2”	
	Lowest:	Buffer category of 0	If D42 = 0, enter “0”	
Vwaterdepth	*Highest:*	Water depths >1 m present	If D12.3 = 1, enter “1”	
	Moderate:	Water depths between 1-100 cm present	If D12.1 = 1 and D12.2 = 1, enter “0.5”	
	Low:	Depths between 1-20 cm present	If D12.1 = 1, enter “0.3”	
	Lowest:	No surface water present	If all D10 are 0, enter “0”	
Vcorridor	*Highest:*	Corridor rating is 3	If D43 = 3, enter “1”	
	Moderate:	Corridor rating is 2	If D43 = 2, enter “0.67”	
	Low:	Corridor rating is 1	If D43 = 1, enter “0.33”	
	Lowest:	Corridor rating is 0	If D43= 0, enter “0”	
Vbrowse	*Highest:*	AU has > 1 ha of woody veg. for beaver in and within 100 m	If D30 =1, enter “1”	
	Lowest:	Does not have the above	If D30 = 0, enter “0”	
Vemergent2	*Highest:*	AU has cover of emergents that is > = 0.4 ha	If (D1xD14.5)/100 > = 0.4, enter “1”	
	Lowest:	AU has no cover of emergents or emergents < 0.4 ha	If (D1xD14.5)/100 < 0.4, enter “0”	
Vwintersp2	*Highest:*	If AU > 0.4 ha and interspersion is high	If D1 > = 0.4 and D38 = 3, enter “1”	
	Moderate:	If AU > 0.4 ha and interspersion is moderate	If D1 > = 0.4 and D38 = 2, enter “0.67”	
	Low:	If AU > 0.4 ha and interspersion is low	If D1 > = 0.4 and D38 = 1, enter “0.33”	
	Lowest:	AU < 0.4 ha OR no interspersion	If D38 = 0 OR D1 < 0.4, enter “0”	
Vow	*Highest:*	If OW > 0.1 ha and OW at least 30% of AU	If (D1 x D8.3)/100 > 0.1 and D8.3 > = 30, enter “1”	
	High:	If OW > 0.1 ha and OW 10 - 29% of AU	If (D1xD8.3)/100 > 0.1 and 10< = D8.3 < 30, enter “0.8”	
	Lowest:	If OW < = 0.1 ha	If (D1xD8.3)/100 < 0.1, enter “0”	
	Calculation:	If OW > 0.1 ha scaled as % OW x 0.08	Enter result of calculation	
	If (D1xD8.3)/100 > 0.1 and D8.3 < 10 calculate as D8.3x0.08 to get result			
Vbank	*Highest:*	Steep banks suitable for denning (>45 degree slope, fine material, >10 m long)	If D37 = 1, enter “1”	
	Lowest:	No steep banks present	If D37 = 0, enter “0”	
				Table continued on next page
Vpermflow	*Highest:*	AU has channel with permanently	If D4.1 = 1, enter “1”	

Variable	Description of Scaling		Score for Variable	Result
		flowing water		
	Lowest:	No channel present	If D4.1 = 0, enter "0"	
Sfish	*Score is scaled*	Index for Habitat Suitability for Fish	Use higher of two indices: (Anadromous Fish)/10 or or (Resident Fish)/10	
			Total of Variable Scores:	
Reducer				
Vupcover	Land use within 1 km - > = 15% urban commercial, or > = 20% high density residential; or > = 40% low density residential		If D3.4 > = 15 OR D3.5 > = 20 OR D3.6 > = 40, enter "0.7"	
	Land use criteria described above not met		If above conditions not met, enter "1"	
			Score for Reducer	
Index for Habitat Suitability for Wetland-associated Mammals = Total for variables x reducer x 1.11 rounded to nearest 1				
			FINAL RESULT:	

9.14 Native Plant Richness — Riverine Impounding Wetlands

Note: Please read the introduction to the assessment models (Chapter 2) before using these models. It describes several basic assumptions used in modeling that will help you better understand how to use and apply the methods.

9.14.1 Definition and Description of Function

Native Plant Richness is defined as the degree to which a wetland provides a habitat for a relatively high number of native plant species.

An AU is judged to provide habitat for native plants if it contains a diverse group of native plants. This function is the only one for which an actual estimate of performance can be made because the number of plant species can be estimated during a single site visit. Many native plants are persistent and can be documented in a rapid assessment method. The assessment of species richness during the site visit is used as a surrogate for the total richness. If an AU contains a diverse and mature assemblage of native plants it is assumed to perform the function at a high level. Those lacking diverse native plant assemblages and structure are assumed to perform the function at a lower level.

Note: The assumption is valid only if the AU has **not** been recently cleared or altered. If you find the AU has been recently altered, the resulting index will not indicate an adequate assessment of the function.

The Assessment Teams considered using the list of native plant communities developed by Kunze (1994) for western Washington as the basis for the assessment. Attempts to identify specific plant associations by name, however, proved too difficult for most investigators not specifically trained as botanists or plant ecologists. The Assessment Teams also judged that AUs containing one or more non-native species as dominants have lost some of the ability to support native plant associations. Non-native plants that become dominant tend to become monocultures that exclude native species. **The percent of the AU dominated, or co-dominated, by non-native species is modeled as a reducer.**

Note: A variable representing invasive **native** species was considered as a reducer of performance. The Assessment Teams, however, decided that the impact of invasive native species was partially addressed in other variables ($V_{prichness}$, V_{assoc}, and V_{strata}). The presence of a native invasive species is reflected in lower scores for those variables. The Assessment Teams judged the presence of non-native species as more detrimental to the performance of this function, and a element of the wetland ecosystem to be highlighted.

9.14.2 Assessing this Function for Riverine Impounding Wetlands

Native Plant Richness in the riverine impounding subclass is assessed by the richness of the existing plant species and associations. Variables include the number of plant associations in the AU, the richness of plant species, and structural elements such as number of strata and the presence of mature trees. The presence of Sphagnum bogs in depressional wetlands is used as an indicator of a potentially very rich native species assemblage that may not be captured by the other variables.

9.14.3 Model at a Glance

Riverine Impounding — Native Plant Richness

Process	Variables	Measures or Indicators
Native plant richness (applies to all variables)	**Vstrata**	Number of strata present in any plant association
	Vassemb	Number of plant assemblages
	Vmature	Presence/absence of mature trees
	Vnplants	Number of native plant species
Reducers		
	Vnonnat	% of AU dominated by non-native plant species

Index: $\dfrac{(\text{Vstrata} + \text{Vassemb} + \text{Vmature} + \text{Vnplants}) \times (\text{Vnonnat})}{\text{Score from reference standard sites}}$

9.14.4 Description and Scaling of Variables

$\boldsymbol{V_{strata}}$ – The maximum number of strata in any single plant association. A plant association can have up to 6 strata (layers: trees, shrub, low shrub, vine, herbaceous, moss). To count as a stratum, however, the plants of that stratum have to have 20% cover in the association in which it is found.

Rationale: Each stratum of a plant association is composed of different plant species. AUs with more strata, therefore, have the potential to support more native plant species than ones with fewer. The number of strata is used as an indicator of plants richness that can be associated with each specific strata that may not be counted during the site visit. These include many mosses and other bryophytes that are not included in a species count.

Indicators: No indicators are needed to assess this variable. The number of strata can be estimated directly at the site.

Scaling: AUs with 5 or 6 strata are scored a [1] for this variable. AUs with only one are scored a [0.2]. AUs with 2-5 strata are scaled proportionally as 0.2, 0.4, 0.6, and 0.8 respectively. For this function, the vine stratum is not counted if it is dominated by non-native blackberries.

$\boldsymbol{V_{assemb}}$ – The number of plant assemblages in the AU.

Rationale: Each plant assemblages represents a different group of plant species. Even if some plant species are the same between associations, the ecological relationships between the species within the associations are probably different, and represent potential differences in phenotypes. The number of associations, therefore, is one way to characterize the richness of plants in an AU. The procedures for collecting data described in Part 2 provide guidance on how to identify associations in the field.

Indicators: No indicators are needed to assess this variable. The number of associations can be determined in the field.

Scaling: Riverine impounding AUs with 9 or more plant associations are scored a [1]. AUs with fewer are scaled proportionally.

$\boldsymbol{V_{mature}}$ – The AU has, or does not have, a stand of mature trees present.

Rationale: The model is giving a point for the presence of a stand of mature trees. A mature stand is used as a surrogate for stability, complexity and structure in plant associations that may not be captured by other variables. The presence of mature trees suggests the AU may contain native plant species that are intolerant of much disturbance and that might not be observed because of their scarcity.

Indicators: This variable is characterized by measuring the dbh (diameter at breast height) of the five largest trees of specific species (see Part 2 for list of species and size criteria). If the average diameter of the three largest of a given species exceed the diameters given in Part 2, the AU is considered to contain a stand of mature trees.

Scaling: This is an "on/off" variable. AUs with mature trees are scored a [1], those without are scored a [0].

$V_{nplants}$ – The number of native plant species present.

Rationale: The number of native plant species assessed during one site visit is one measure of how effective an AU is at providing a diverse habitat for native plants and maintaining regional plant biodiversity. It is not possible, however, to determine the total species richness in one visit and within a few hours. Some plants are annuals and grow for only a short time, others have a very limited distribution and may occupy a small and inconspicuous patch that is easily overlooked. For this reason the count of native species determined during the site visit is only an indicator of the actual number present.

Indicators: The indicator of overall native plant richness is the number of native species found during the site visit.

The Assessment Teams recognize that observations done during the summer may result in a higher count of plant species than if done in the winter. This question remains unresolved as most of our calibration occurred during the summer and fall. A different scaling may be developed for winter and summer if further data necessitates.

Scaling: If the AU has 30 or more native species it is scored a [1]. AUs with a fewer number of native species are scaled proportionally (# of native species/30).

$V_{nonative}$ – The percent of the AU where non-native species are dominant or co-dominant (non-native species are listed in Part 2, Appendix L) **This is a variable of reduced performance.**

Rationale: The Assessment Teams judged that wetlands where one or more of the dominant species is non-native have lost some of their potential for maintaining native regional plant biodiversity. Non-native plants that become dominant tend to exclude many of the less common native plants.

Indicators: No indicator is needed for this variable. The areal extent of non-native species can be determined in the field.

Scaling: AUs where non-native species extend over more than 75% of the AU have their index reduced by a factor of 0.5. Those with an extent of 50 – 75% are reduced by a factor of 0.7, and those with an extent of non-native between 25-49% are reduced by a factor of 0.9. AUs where non-native species are dominant or co-dominant on less than 25% of the AU do not have their index reduced.

9.14.5 Calculation of Index

Riverine Impounding – Native Plant Richness

Variable	Description of Scaling		Score for Variable	Result
Vstrata	*Highest:*	5 strata present (no blackberries)	If D21 - D21.1 = 5, enter "1"	
	High:	4 strata present (no blackberries)	If D21 - D21.1 = 4, enter "0.8"	
	Moderate:	3 strata present (no blackberries)	If D21 - D21.1 = 3, enter "0.6"	
	Medium Low:	2 strata present (no blackberries)	If D21 - D21.1 = 2, enter "0.4"	
	Low:	1 stratum present (no blackberries)	If D21 - D21.1 = 1, enter "0.2"	
	Lowest:	Only stratum = blackberries	If D21 - D21.1 = 0, enter "0"	
Vassemb	*Highest:*	AU has at least 9 plant assemblages	If calculation > = 1, enter "1"	
	Lowest:	AU has 1 plant assemblage	If D20 = 1, enter "0.1"	
	Calculation:	Scaling based on the number of assemblages divided by 10	Enter result of calculation	
	Calculate D20/9 to get result			
Vmature	*Highest:*	AU has mature trees present	If D22 = 1, enter "1"	
	Lowest:	AU has no mature trees present	If D22 = 0, enter "0"	
Vnplants	*Highest:*	Number of native plant species > = 30	If calculation > = 1, enter "1"	
	Lowest	AU has 1 or less native species	If D19.1 < = 1, enter "0"	
	Calculation:	Scaled as # of native species/30	Enter result of calculation	
	Calculate (D19.1)/30 to get result			
			Total of Variable Scores:	
Reducer				
Vnonnat	>75% cover of non-native plants		If D24.1 = 1, enter "0.5"	
	50-75% cover of non-native plants		If D24.2 = 1, enter "0.7"	
	25 - 49% cover of non-native plants		If D24.3 = 1, enter "0.9"	
			Score for Reducer:	
Index for Native Plant Richness = Total for variables x reducer x 2.5 rounded to nearest 1				
			FINAL RESULT:	

9.15 Potential for Primary Production and Organic Export — Riverine Impounding Wetlands

Note: Please read the introduction to the assessment models (Chapter 2) before using these models. It describes several basic assumptions used in modeling that will help you better understand how to use and apply the methods.

9.15.1 Definition and Description of Function

The function of Primary Production and Organic Export is defined as wetland processes that result in the production of plant material and its subsequent export to surface waters.

Wetlands are known for their high primary productivity (variously expressed as gm-Carbon/m^2 /year or as total biomass) and the subsequent export of organic matter to adjacent aquatic ecosystems (Mitch and Gosselink 1993). In some cases, wetlands may be highly productive, but most of the organic material produced is retained within the wetland where it originates (e.g. high salt marshes or coniferous forests). Alternatively, in some wetlands production may be lower, but most of it is exported (e.g. riverine marshes). **Performance of this function requires both that organic material is produced and a mechanism is available to move the organic matter to adjacent or contiguous aquatic ecosystems**. The exported organic matter provides an important source of food for most downstream aquatic ecosystems (Mitch and Gosselink 1993).

9.15.2 Assessing this Function for Riverine Impounding Wetlands

The potential of an AU in the riverine impounding subclass to produce and export organic matter is modeled as two separate processes 1) production of organic materials; and, 2) movement of organic material out of the AU. Amount of production is most directly related to presence of plant cover ($V_{vegcover}$). Variables are then added to reflect type of vegetation ($V_{non\text{-}evergreen}$ *and* $V_{understory}$). The vegetation variables are not chosen to reflect higher rates of primary production, rather they reflect types of vegetation that decompose more readily. Although there seems to be a commonly held hypothesis that herbaceous vegetation is more productive than woody vegetation, the literature is inconclusive on this issue. For example, evergreen coniferous forests (e.g. western hemlock) can be as productive as some of the most productive herbaceous sites (e.g. cattail marshes) (Franklin and Dyrness 1973, Mitch and Gosselink 1993). Other literature simply records high production for systems described as “marshes and swamps” without distinguishing based on vegetative cover type.

The principal reason for adding a variable to reflect vegetation type is to capture the variability in rate of decomposition of the organic matter produced, and, therefore, the ease of export. The model recognizes that herbaceous and deciduous plant material is easily decomposed and much of the above ground annual production is available for export as dissolved organic matter.

The equation is structured so that an AU receives a basic score based on the percent of the AU that is vegetated ($V_{vegcover}$). The score is increased if part of that total vegetation is either herbaceous, aquatic bed, or deciduous woody to reflect the less refractory nature of these vegetation types. The model assumes that non-deciduous (evergreen) coniferous needles are the most refractory and least usable by adjacent ecosystems (even toxic in some cases). Thus no additions to the score are made for presence of conifer cover. An additional variable is included to model the herbaceous understory that may be present in forested or scrub/shrub Cowardin vegetation classes, since the understory is an additional source of labile organic matter.

The second part of the model includes variables that model the ability of the wetland to move material to adjacent aquatic ecosystems. Riverine impounding AUs have a surface water outlet by definition, and therefore can export the organic matter produced. An estimate of how much of the organic matter produced within the AU can be exported is provided by the variable ($V_{effectarea1}$) that reflects the area of the AU that is seasonally inundated. Organic matter can be exported only where surface water is present that can carry the material away. One indication that the export of organic matter is not very efficient in an AU is the presence of organics oils, and a variable is included to reflect this (V_{org}). AUs with less area covered by organic soils are judged to be better at exporting than those with more.

9.15.3 Model at a Glance

Riverine Impounding — Potential for Primary Production and Organic Export

Process	Variables	Measures or Indicators
Primary Production	**Vvegcover**	% of AU with vegetation cover

Primary Production	**Vnon-evergreen**	% area of all non-evergreen vegetation
Primary Production	**Vunderstory**	% area of herbaceous understory in AU
Export	**Vorg**	Extent of organic soils in AU
Export	**Vout**	Characteristics of outlet constriction

Index:

$$\frac{(V_{vegcover} + V_{non\text{-}evergreen} + V_{understory}) \times (V_{org} + V_{out})}{\text{Score from reference standard site}}$$

9.15.4 Description and Scaling of Variables

$V_{vegcover}$ **–** The percent of the total area of the AU is covered by plants.

Rationale: The assumption made by the Assessment Teams is that the average amount of primary production per acre in an AU is most directly related to the amount of its total plant cover.
Indicators: No indicators are needed for this variable. The areal extent of vegetation can be determined from field visits or aerial photographs.
Scaling: An AU that is completely vegetated (100% of AU) is scored a [1]. AUs where the vegetated area is less, because of open water or mudflats, are scored proportionally (%area/100).

$V_{non\text{-}evergreen}$ **–** The percent of the AU that is dominated by deciduous (non-evergreen) vegetation (emergent, deciduous forest, deciduous scrub/shrub, and aquatic bed).

Rationale: This variable is chosen to reflect the types of vegetation that decompose more readily and are, therefore, more exportable.
Indicators: The indicator for this variable is the area that would be classified as emergent, deciduous forest, deciduous scrub/shrub, and aquatic bed using the Cowardin classification (Cowardin et al. 1979).
Scaling: An AU that is completely vegetated with emergent, deciduous forest, deciduous scrub/shrub, and aquatic bed (100% of area when all are added together) is scored a [1]. AUs where the total area of these vegetation classes is lower are scored proportionally (total %area/100).

$V_{understory}$ **–** Percent of the AU where an herbaceous understory provides at least a 20% cover under areas of forest or scrub/shrub vegetation classes.

Rationale: An additional variable is included to model the herbaceous understory that may be present in a forested or scrub shrub Cowardin vegetation class. The understory is an additional source of labile organic matter that is not captured in the other vegetation variables.
Indicators: No indicators are needed. The % areal extent of herbaceous understory is estimated during the field visit.
Scaling: If 100% of the AU has an herbaceous understory it is scored a [1]. AUs where understory is less are scored proportionally (% area/100).

V_{org} **–** The area of the AU (as %) that is covered by organic soils.

Rationale: One indication that the export of organic matter is not very efficient in an AU is the presence of organic matter in the soils. The Assessment Teams have assumed that AUs with no organic soils are probably better at exporting than those with some.
Indicators: The extent of different soils types can be determined during the site visit.
Scaling: AUs with less than 1% area of organic soils score a [1]. Those with <50% organic soils score a 0.8; those with 51-95% score a [0.3]; and those with >95% organic soils score a [0].

V_{out} – The wetland has a perennial or seasonal surface water outflow through a defined channel that can be characterized by its amount of constriction.

Rationale: Although a flooding event will re-suspend and export organic matter from a wetland regardless of whether it has an outlet or not, the presence of an outlet channel facilitates export. The presence of an outlet will usually increase the amount of flow out of an AU. If the AU has no outlet, its berms will act like a dam and trap material within the AU.
Indicators: No indicators are needed. The relative width of the outlet is determined directly in the field.

Scaling: The scaling of this variable is based on the amount of constriction found in the AU.

Unconstricted or slightly constricted – The outlet allows water flow out of the AU during the wet season across a wide distance. The outlet does not provide much hindrance to waters coming downstream. In general, the distance between the low point of the outlet and inundation height (D28) will be small (< 30 cm – 1 ft). Beaver dams are considered unconstricted unless they are anchored to steep bank on either side because they are usually wide and do not retard flows once the water reaches the crest. Unconstricted or slightly constricted outlets are scored a [1].

Moderately constricted – The outlet is small or narrow enough to hold back some water during the wet season. The outlet is categorized as moderately constricted if it cannot be categorized as either unconstricted or severely constricted. Moderately constricted outlets are scored a [0.5].

Severely constricted – These are small culverts or heavily incised channels anchored to steep slopes. In general, you will find marks of flooding or inundation a meter or more above the bottom of the outlet. Another indicator of a severely constricted outlet is evidence of erosion on the downstream side of the outlet. Severely constricted outlets are scored a [0.3].

No outlet – Surface water does not leave the wetland through any type of channel; rather it leave the wetland by sheetflow over a berm or dike. No outlets are scaled as [0.1].

9.15.5 Calculation of Potential Performance

Riverine Impounding – Primary Production and Organic Export

Variable	Description of Scaling		Score for Variable	Result
Vvegcover	*Highest:*	AU is100% vegetated	If calculation =1, enter "1"	
	Lowest:	AU has minimal vegetation cover	If calculation = <0.05, enter "0"	
	Calculation:	Scaling is set as % vegetated/100	Enter result of calculation	
	Calculate [sum (D14.1 to D14.6)] /100 to get result			
Vnonevergreen	*Highest:*	100% of AU has cover of non-evergreen vegetation	If calculation = 1, enter "1"	
	Lowest:	AU has only evergreen vegetation	If calculation = 0, enter "0"	
	Calculation:	Scaled as a fraction based on % area	Enter result of calculation	
	Calculate (D14.2 + D14.4 + D14.5 + D14.6) / 100 to get result			
Vunderstory	*Highest:*	AU has 100% herbaceous understory	If calculation = 1.0 enter "1"	
	Lowest:	AU has no understory	If D16 = 0, enter "0"	
	Calculation:	Scaling based on understory as % of the total area of AU	Enter result of calculation	
	Calculate (0.01 x D16) x (D14.1 + D14.2 + D14.3 + D14.4)/100 to get result			
			Total of Variables for Primary Production:	
Vout	*Highest:*	Slightly or unconstricted	If D13.1 = 1 enter "1"	
	High:	Moderately constricted	If D13.2 = 1, enter "0.8"	
	Moderate:	Severely constricted	If D13.3 = 1, enter "0.5"	
	Lowest::	No outlet	If D13.4 = 1, enter "0.1"	
Vorg	*Highest:*	AU has no organic soils	If D47.1 + D47.2 = 0, enter "1"	
	Moderate:	AU has some organic soils but < 50%	If D47.1 + D47.2 < = 1, enter "0.8"	
	Low:	AU has > 50% and < 95% organic soils	If D47.1 or D47.2 = 2, enter "0.3"	
	Lowest:	AU has > 95% organic soils	If D47.1 or D47.2 = 3, enter "0"	
			Total of Variables for Export:	
Reducer				
Vbogs	Bog component > 75% of AU		If D23.1 = 1, enter "0.5"	
	Bog component 50-75% of AU		If D23.2 = 1, enter "0.7"	
	Bog component 25-49% of AU		If D23.3 = 1, enter "0.9"	
	Bog component < 25% of AU		If D23.4 + D23.5 = 1, enter "1"	
			Score for Reducer	
Index for Primary Production and Export = (Total for production x total for export) x Reducer x 1.85 rounded to nearest 1				
			FINAL RESULT:	

References Cited

Adamus, P. R., E. J. Clairain, Jr., R. D. Smith, and R. E. Young. 1987. Wetland Evaluation Technique (WET), Volume II: Methodology. Department of the Army, Waterways Experiment Station, Vicksburg, MS. NTIS No. ADA 189968.

Adamus, P. R., L. T. Stockwell, E. J. Clairain, Jr., M. E. Morrow, L. P.Rozas, and R. D. Smith. 1991. Wetland Evaluation Technique (WET), Volume I: Literature Review and Evaluation Rationale. US Army Corps of Engineers, Waterways Experiment Station, Wetlands Research Program Technical Report WRP-DE-2, Vicksburg, MS.

Allen, A.W. 1983. Habitat Suitability Index Models: Beaver. US Fish and Wildlife Service publication number FWS/OBS-82/10.30 Revised.

Allen, A.W. and R.D. Hoffman. 1984. Habitat Suitability Index Models: Muskrat. US Fish and Wildlife Service publication number FWS/OBS-82/10.46.

Ammann, A.P., R.W. Franzen, and J.L. Johnson. 1986. Method for the Evaluation of Inland Wetlands in Connecticut. DEP Bulletin No. 9. Connecticut Department of Environmental Protection, Hartford, CT.

Anderson, J.D. 1967. A comparison of the life histories of coastal and montane populations of *Ambystoma macrodactylum* in California. The American Midland Naturalist 77:323-355.

Andrewartha, H. G., and L. C. Birch. 1984. The Ecological Web: More on the Distribution and Abundance of Animals. University of Chicago Press, Chicago, IL.

Andrews, J. D., and A. D. Hasler. 1943. Fluctuations in the animal populations of the littoral zone in Lake Mendota. Transactions,Wisconsin Academy of Sciences, Arts, and Letters 35:175-185.

Azous, A. L. and K.O. Richter. 1995. Amphibian and plant community responses to changing hydrology in urban wetlands. Pp. 156-162 in E. Robichaud (ed.) Puget Sound Research 1995 Proceedings, Volume 1, Puget Sound Water Quality Authority, Olympia, WA.

Beebee, T. C. J. 1996. Ecology and Conservation of Amphibians. Chapman & Hall, London, England

Beneski, J. T. Jr., E.J. Zalisko and J.H. Larsen Jr. 1986. Demography and migratory patterns of the eastern long-toed salamander, *Ambystoma macrodactylum columbianum*. Copeia 1986:398-408.

Berven, K.A. and T.A. Grudzien. 1990. Dispersal in the wood frog (*Rana sylvcatica*): Implications for genetic population structure. Evolution 44:2047-2056.

Bisson, P.A., R.E. Bilby, M.D. Bryant, C.A. Doloff, G.B. Grette, R.A. House, M.L. Murphy, K.V. Koski and J.R. Sedell. 1987. Large woody debris in forested streams in the Pacific Northwest: past, present and future. Pp. 143-190 in E.O. Salo and T.W. Cundy, eds. Streamside management: forestry and fishery interactions. University of Washington, Institute of Forest Resources, Seattle, WA.

Bjornn T.C. and D.W. Resier. 1979. Habitat requirements of anadromous salmonids. In W.R. Meehan (ed.) Influence of forest and rangeland management on anadromous fish habitat in the western US and Canada. USDA Forest Service, General Technical Report PNW 96.

Bormann, F.H., G.E.Likens, T.G.Sicama, R.S. Pierce, and J.S. Eaton. 1974. The export of nutrients and recovery of stable conditions following deforestation at Hubbard Brook. Ecological Monographs 44:255-277.

Bradford, D.F. 1991. Mass mortality and extinction in a high-elevation population of *Rana muscosa*. Journal of Herpetology 25:174-177.

Bradt, G.W. 1938. A study of beaver colonies in Michigan. Journal of Mammology 19:139-162.

Brenner, F.J. 1962. Food consumed by beavers in Crawford County, Pennsylvania. Journal of Wildlife Management 26(1): 104-107.

Brinson, M.M. 1993. A Hydrogeomorphic Classification for Wetlands. Technical Report WRP-DE-4. US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Brinson, M.M., F.R. Hauer, L.C. Lee, W.L. Nutter, R.D. Rheinhardt, R.D. Smith, and D. Whigham. 1995. Guidebook for Application of Hydrogeomorphic Assessments to Riverine Wetlands (Operational Draft). US Army Engineers Waterways Experiment Station Technical Report WRP-DE-11. Vicksburg, MS.

Burgess, S.A. 1978. Aspects of mink (*Mustela vison*) ecology in the Southern Laurentains of Quebec. M.S. Thesis. MacDonald College of McGill University, Montreal, Quebec.

Bury, R. B. and P. S. Corn. 1988. Douglas fir forest in the Oregon and Washington Cascades: relation of the herpetofauna to stand age and moisture. Pp. 11-22 in R.C. Szaro, K.W. Severson, and D.R. Patton, (tech. coords.). Management of amphibians, reptiles, and small mammals in North America. US Department of Agriculature, Forest Service, Rock Mountain Forest and Range Experiment Station, Fort Collins, CO. General technical report RM-166.

Chang, M., J.D. McCollough, and A.B. Granillo. 1983. Effects of land use and topography on some water quality variables in forested east Texas. Waster Resources Bulletin 19:191-196.

Chapman, D.W. 1966. The relative contributions of aquatic and terrestrial primary producers to the trophic relations of stream organisms. Pp. 116-130 in: Organism-substrate relationships in streams. PymantuningLab. Ecological Special Publication No. 4. University of Pittsburgh, Pittsburgh, PA.

Cooke, S. Cooke Scientific Services, Inc. Seattle, WA. Personal communication. 1997.

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe. 1979. Classification of Wetlands and Deepwater Habitats of the United States. US Fish and Wildlife Service, Washington, DC.

Cyr, H., and J. A. Downing. 1988. The abundance of phytophilous invertebrates on different species of submerged macrophytes. Freshwater Biology 20:365-374.

Davis, J. W., G. A. Goodwin, and R. A. Ockenfels, Coordinators. 1983. Snag Habitat Management: Proceedings of the Symposium, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, General Technical Report RM – 99.

Davis, M. M., E. J. Clairain, Jr., W. Ainslie, M. Gilbert, M.A. Schwinn, M.Sheehan, G. Sparks, K. Trott, and M. Whited. 1995. Development of Regional Wetland Subclass HGM Functional Assessment Model Guidebooks. US Army Engineers Waterways Experiment Station. November Draft.

Denney, R.N. 1952. A summary of North American beaver management. 946-1948. Colorado Fish Game Department Report Number 28, Colorado Division of Wildlife.

Desbonnet, A., P. Pogue, V. Lee, and N. Wolff. 1994. Vegetated buffers in the coastal zone – A summary review and bibliography. Coastal Resources Center Technical Report No. 2064. University of Rhode Island Graduate School of Oceanography. Narragansett RI.

Dougherty, J. E., and M. D. Morgan. 1991. Benthic community response (primarily *Chironomidae*) to nutrient enrichment and alkalinization in shallow, soft water humic lakes. Hydrobiologia 215:73-82.

Dozier, H.L. 1953. Muskrat production and management. US Fish and Wildlife Service Circular No. 18.

Dunstone, N. 1978. The fishing strategy of the mink (*Mustela vison*); time-budgeting of hunting effort? Behaviour 67(3-4): 157-177.

Dupuis, L. A., J.N.M. Smith and F. Bunnell. 1995. Relation of terrestrial-breeding amphibian abundance to tree-stand age. Cons. Biol. 9:645-653.

Dvorak, J. and E.P.H. Best. 1982. Macro-invertebrate communities associated with the macrophytes of Lake Vechten: structural functional relationships. Hydrobiologia 95:115-126.

Earhart, C.M. 1969. The influence of soil texture on the structure, durability, and occupancy of muskrat burrows in farm ponds. California Fish and Game 55(3):179-196.

Eberhardt, R.T. and A. Sargeant. 1977. Mink predation on prairie marshes during the waterfowl breeding season. Pp. 33-43 in R.L. Phillips and C. Jonkel, (eds.) Proceedings of the 1975 Predator Symposium. Montana Forest and Conservation Experiment Station, University of Montana, Missoula, MT.

Errington, P.L. 1937. Habitat requirements of stream-dwelling muskrats. Trans. N. Am. Wildl. Conf. 2:411-416.

Errington, P.L. 1963. Muskrat populations. Iowa State Univ. Press, Ames, IA.

Fennessey, M.S., C.C. Brueske, and W.J. Mitch. 1994. Sediment deposition patterns in restored freshwater wetlands using sediment traps. Ecological Engineering 3:409-428.

Franklin, J. F., and C. T. Dyrness. 1973. Natural Vegetation of Oregon and Washington, USDA Forest Service, Pacific Northwest Range and Experiment Station, General Technical Report PNW-8.

Gibbs, J. P. 1991. Spatial relationships between nesting colonies and foraging areas of great blue herons. Auk 108:764-770.

Gibbs, J. P., J. R. Longcore, D. G. McAuley, and J. K. Ringelman. 1991. Use of Wetland Habitats by Selected Nongame Water Birds in Maine. USDI Fish and Wildlife Service, Fish and Wildlife Research 9.

Giger, R.D. 1973. Streamflow requirements of salmonids. Oregon Wildlife Commission, Final Report Project AFS-62-1. Portland, OR.

Gilfillan, M. C. 1947. Testing methods of increasing muskrat populations. Ohio Div. Conserv. Nat. Resour., Proj. W-0150R-04.

Gill, D.E. 1978a. Effective population size and interdemic migration rates in a metapopulation of the red-spotted newt, *Notopthalmus viridescens* (Rafinesque). Evolution 32:839-849.
Gill, D.E. 1978b. The metapopulation ecology of the red-spotted newt, *Notopthalmus viridescens* (Rafinesque). Ecological Monographs 48:145-166.
Golet, F.C. and J.S. Larson. 1974. Classification of freshwater wetlands in the glaciated Northeast. Resource Publication 116. US Fish and Wildlife Service, Washington DC.
Gorman, O.T. and J.R. Karr. 1978. Habitat structure and stream fish communities. Ecology 59:507-515.
Groot, C., and L. Margolis. 1991. Pacific Salmon Life Histories, University of British Columbia Press, Vancouver, BC.
Hall, J.G. 1970. Willow and aspen in the ecology of beaver in Sagehen Creek, California. Ecology 41(3): 484-494.
Hammer, D.A. 1989. Protecting water quality with wetlands in river corridors. In: J.A. Kusler and S. Daly (eds). Wetlands and River Corridor Management. Association of State Wetland Managers, Berne, NY.
Hartmann, G.F., J.C. Scrivener, and M.J. Miles. 1996. Impacts of logging in Carnation Creek, a high energy coastal stream in British Columbia, and their implications for restoring fish habitat. Canadian Journal of Fisheries and Aquatic Science 53:237-251.
Heusser, H. 1968. Die Lebensweise der Erdkrote, *Bufo bufo L.*: Wanderungen und Sommerquartiere. Rev. Suis. Zool. 76:444-517.
Hicks, A. 1995. Impervious surface area and benthic macroinvertebrate response as an index of impact from urbanization on freshwater wetlands. M.S. Thesis, University of Massachusetts, Amherst, MA.
Hicks, A. L. 1996. Aquatic invertebrates and wetlands: ecology, biomonitoring and assessment of impact from urbanization. Pp. 130. in A. L. Hicks (ed.) University of Massachusetts, Amherst, MA.
Horner, R. 1992. Constructed Wetlands for Storm Runoff Water Quality Control - Course Materials. Center for Urban Water Resources Management, University of Washington, Seattle, WA.
Hruby, T., W.E. Cesanek, and K.E. Miller. 1995. Estimating relative wetland values for regional planning. Wetlands 15:93-107.
Hunter, M. L., Jr. 1996. Fundamentals of Conservation Biology, Blackwell Science, Cambridge, MA.
Ildos, A.S. and N. Ancona. 1994. Analysis of amphibian habitat preferences in a farmland area - Po Plain, northern Italy. Amphibia-Reptilia 15:307-316.
Jackson, H.O. and W.C. Starrett. 1959. Turbidity and sedimentation in Lake Chatuqua, Illinois. Journal of Wildlife Management 23:157-168.
Jenkins, S.H. 1981. Problems, progress, and prospects in studies of food selection by beavers. Pp. 559-579 in J.A. Chapman and D. Pursley (eds.) Worldwide Furbearer Conference Proceedings, Volume 1.
Johnson, A.W. and J.M Stypula (eds.). 1993. Guidelines for Bank Stabilization Projects in the Riverine Environments of King County, KCDPW, Seattle.
Johnson, R. R., and D. A. Jones. 1977. Importance, Preservation and Management of Riparian Habitat: A Symposium, USDA Forest Service, Rocky Mountain Range and Experiment Station, General Technical Report RM-43.
Karr, J.R. and I.J. Schlosser. 1977. Impact of nearstream vegetation and stream morphology on water quality and stream biota. EPA 600/3-77-097. US Environmental Protection Agency, Washington DC.
King, C.M. 1983. Factors regulating mustelid populations. Acta Zool. Fenn. 174:217-220.
Kulzer, L. 1990. Water Pollution Control Aspects of Aquatic Plants: Implications for Stormwater Quality Management. Municipality of Metropolitan Seattle.
Kunze, L.M. 1994. Preliminary classification of native, low elevation, freshwater wetland vegetation in western Washington. Washington Natural Heritage Program, Department of Natural Resources, Olympia, WA.
Leonard, W.P. and K.O. Richter. 1994. Long-toed salamander *(Ambystoma macrodactylum)* breeding habitat in a small vernal wetland in the Puget Sound Lowlands; p. 96 in Wetlands: Local Functions, Global Dependence Abstracts of the Society of Wetland Scientists 15th Annual Meeting, May 30 – June 3rd, Portland, OR.
Licht, L.E. 1969. Comparative breeding behavior of the red-legged frog (*Rana aurora aurora*) and the western spotted frog (*Rana pretiosa pretiosa*) in southwestern British Columbia. Canadian Journal of Zoology 47:1287-1299.

Linscombe, G., N. Kinler, and R. Aulerich. 1982. Mink (*Mustela vison*). Pp. 629-643 in J.A. Chapman and G.A. Feldhamer, (eds.) Wild mammals of North America: biology, management, and economics. Johns Hopkins University Press, Baltimore, MD.

Lodge, D.M. 1985. Macrophyte-gastropod associations: Observations and experiments on macrophyte choice by gastropods. Freshwater Biology 15:695-708.

Loredo, I., D. VanVuren, and M.L. Morrison. 1996. Habitat use and migration behavior of the California tiger salamander. Journal of Herptology 30:282-285.

Ludwa, K.A. 1994. Urbanization effects on palustrine wetlands: empirical water quality models and development of a macroinvertebrate community-based biological index. M S Thesis, University of Washington, Seattle, WA.

Maser, C., R. F. Tarrant, J. M. Trappe, and J. F. Franklin. 1988. From the forest to the sea: A story of fallen trees. USDA Forest Service, Pacific Northwest Research Station, General Technical Report PNW-GTR-229.

McGarrigle, M. L. 1980. The distribution of *Chironomos* communities and controlling sediment parameters in L. Derravaragh, Ireland. Pp. 275-282 in D. A. Murray, (ed.) *Chironomidae*: Ecology, Systematics, Cytology and Physiology. Pergamon Press, Oxford, CT and New York, NY.

McMahon, T.E. 1983. Habitat Suitability Index Models: Coho Salmon. FWS/OBS-82/10.49. USDI Fish and Wildlife Service, Habitat Evaluation Procedure Group, Ft. Collins, CO.

Melquist, W.E. and M.G. Hornocker. 1983. Ecology of river otters in west central Idaho. Journal of Wildlife Management Wildlife Monograph No. 83, Vol. 47, No. 2.

Melquist, W.E., J. Whitman, and M.G. Hornocker. 1981. Resource partitioning and coexistence of sympatric mink and river otter populations. Pp. 187-220 in: J.A. Chapman and D. Parsley (eds.) Worldwide Furbearer Conference Proceedings.Volume 1. Frostberg, MD.

Mengel, K. and E.A. Kirkby. 1982. Principles of Plant Nutrition. 3rd edition. International Potash Institute Switzerland.

Milligan, D.A. 1985. The Ecology of Avian Use of Urban Freshwater Wetlands in King County, Washington, Thesis submitted in partial fulfillment of degree. University of Washington, College of Forest Resources, Seattle, WA.

Minshall, G. W. 1984. Aquatic insect-substratum relationships. Pp. 358-400 in V. R. and D. M. Rosenberg (eds.) The Ecology of Aquatic Insects. Praeger, New York, NY.

Mitsch, W.J. and J.G. Gosselink. 1993. Wetlands. Van Nostrand Reinhold Co., New York, NY.

Mitsch, W.J., J.K. Cronk, X. Wu, and R.W. Nairn. 1995. Phosphorus retention in constructed freshwater riparian marshes. Ecological Applications 5:830-845.

Mongillo, P. Washington Department of Fish and Wildlife. Fish biologist. Olympia, WA.

Murkin, H. R., and B. D. J. Batt. 1987. The interactions of vertebrates and invertebrates in peatlands and marshes. Memoirs of the Entomological Society of Canada. 140:15-30.

Narver, D.W. 1978. Ecology of juvenile coho salmon - Can we use present knowledge for stream enhancement? Pp. 38-43 in: B.G. Shepherd and R.M.J Ginetz. Proceedings of the 1977 Northeast Pacific Chinook and Coho Salmon Workshop. Fish. Mar. Ser. (Can.) Tech. Rep. 759:164 Pp. in Groot, C., and L. Margolis, 1991. Pacific Salmon Life Histories, University of British Columbia Press, Vancouver.

Needham, J.G. and P.R. Needham. 1962. A guide to the study of fresh-water biology. Holden-Day Inc. San Francisco, CA.

Pechmann, J.H.K. and H.M. Wilbur. 1994. Putting declining amphibian populations in perspective: Natural fluctuations and human impacts. Herpetologica 50:65-84.

Peterson, N.P. 1982. Population characteristics of juvenile coho salmon overwintering in riverine ponds. Canadian Journal of Fisheries and Aquatic Science. 39: 1 303-1307

Phipps, R.G. and W.G. Crumpton. 1994. Factors affecting nitrogen loss in experimental wetlands with different hydrologic loads. Ecological Engineering 3:399-408.

Pounds, J.A. and M.L. Crump. 1994. Amphibian declines and climate disturbance: the case of the golden toad and the harlequin frog. Conservation Biology 8:72-85.

Reeves, G.H. et. al. 1989. Identification of physical habitats limiting the production of coho salmon in western Washington and Oregon. USDA Pacific Northwest Research Station, General Technical Report PNW-GTR-245.

Reinelt, L.E. and Horner, R.R. 1995. Pollutant removal from stormwater runoff by palustrine wetlands based on comprehensive budgets. Ecological Engineering 4:77-97.

Reinelt, L.E. and R.R. Horner. 1990. Characteristics of the hydrology and water quality of palustrine wetlands affected by urban stormwater. King County Resource Planning, Seattle, WA.

Reppert, R.T., W. Sigleo, E. Stakhiv, L. Messman, and C. Beyers. 1979. Wetland Values: Concepts and Methods for Wetland Evaluation. US Army Corps of Engineers, Institute for Water Resources, Fort Belvoir, VA.

Richter, K.O. King County Department of Natural Resources, Senior Ecologist. Personal observation. 1993 – 1997.

Richter, K.O. 1997. Criteria for the restoration and creation of wetland habitats of lentic-breeding amphibians of the Pacific Northwest. Pp. 72-94 in K.B. Macdonald and F. Weinmann (eds.), Wetland and Riparian Restoration: Taking a Broader View. Publication EPA 910-97-007. USEPA, Region 10, Seattle, WA.

Richter, K.O. and A.L. Azous. In preparation. Bird distribution, abundance and habitat use. In Azous, A.L. and Horner, R.R., (eds.) Wetlands and Urbanization. Lewis Publishers, New York.

Richter, K.O. and A.L. Azous. 1995. Amphibian occurrence and wetland characteristics in the Puget Sound Basin. Wetlands 15:305-312.

Richter, K.O. and H. Rougharden. In preparation. Wetland characteristics and oviposition site selection by the Northwestern salamander *(Ambystoma gracile)*. Draft manuscript. King County Department of Natural Resources, Water and Land Resources Division, Seattle, WA.

Rosenberg, D. M., and H. V. Danks. 1987. Aquatic Insects of Peatlands and Marshes in Canada. Memoirs of the Entomological Society of Canada No. 140:174.

Rosenberg, D. M., and V. H. Resh. 1996. Use of aquatic insects in biomonitoring. Pp. 87-97 in R. W. Merritt and K. W. Cummins (eds.) An Introduction to the Aquatic Insects of North America. Kendall/Hunt Publishing Company, Dubuque, IO .

Rowe, C.L., W.J. Sadinski and W.A. Dunson. 1992. Effects of acute and chronic acidification on three larval amphibians that breed in temporary ponds. Archives of Environmental Contamination and Toxicology 23:472-476.

Sadinski, W.J. and W.A. Dunson. 1992. A mulit-level study of the effects of low pH on amphibians of temporary ponds. Journal of Herpetology 26:413-422.

Schueler, T. 1994. The importance of imperviousness. Watershed Protection Techniques 1:100-111.

Schuett-Hames, D., A. Pleus, L. Bullchild, and S. Hall (eds.). 1994. Timber Fish and Wildlife Ambient Monitoring Program Manual. Northwest Indian Fisheries Commission, Olympia, WA.

Semlitsch, R.D. 1981. Terrestrial activity and summer home range of the mole salamander (*Ambystoma talpoideum*). Canadian Journal of Zoology 59:315-322.

Sinsch, U. 1992. Structure and dynamic of a natterjack toad metapopulation (*Bufo calamita*). Oecologia 90:489-499.

Slater, J.R. 1936. Notes on *Ambystoma gracile Baird* and *Ambystoma macrodactylum Baird*. Copeia 1936:234-236.

Slough, B.G. and R. Sadleir. 1977. A land capacity classification system for beaver (*Castor canadensis*). Canadian Journal of Zoology 55(8):1324-1335.

Smith, Dave. US Army Corps of Engineers. Waterways Experiment Station. Personal Communication.

Smith, R.A. and V. McDaniel 1982. A two year comparison of the winter food habits of mink (*Mustela vison*) from Deltaic Northeast Arkansas. Arkansas Acad. Sci. Proc. 36:103-106.

Smith, R.D., A. Ammann, C. Bartoldus, and M.M. Brinson. 1995. An Approach for Assessing Wetland Functions Using Hydrogeomorphic Classification, Reference Wetlands, and Functional Indices. US Army Engineers Waterways Experiment Station, Technical Report WRP-DE-10, and Operational Draft, Vicksburg, MS.

Sofgren, G. P. 1991. Extinction and isolation gradients in metapopulations: The case of the pool frog (*Rana lessonae*). Biological Journal of the Linnean Society (London) 42:135-147.

Sofgren, G. P. 1994. Distribution and extinction patterns within a northern metapopulation of the pool frog *Rana lessonae*. Ecology 75:1357-1367.

Starfield, A.M., B.P. Farm and R.H. Taylor. 1989. A rule-based ecological model for the management of an estuarine lake. Ecological Modeling 46:107-119.

Strijbosch, H. 1979. Habitat selection of amphibians during their aquatic phase. Oikos 33:363-372.

Terrell, J.W., T.E. McMahon, P.D. Inskip, R.F. Raleigh, and K.L. Williamson. 1982. Habitat suitability index models: Appendix A-Guidelines for riverine and lacustrine applications of fish HSI models with the Habitat Evaluation Procedures. US Fish and Wildlife Service FWS/OBS-82/10.A.

Thomas, J.W., C. Maser, and J.E. Rodiek. 1978. Edges- their interspersion, resulting diversity and measurement. Pp. 91-110 in: DeGraaf, R.M. (ed.) Proceedings of the workshop on nongame bird management in the coniferous forests of the Western United States. Northwest Forest and Range Experiment Station.

USDI. 1978. Terrestrial Habitat Evaluation Criteria Handbook for Ecoregion 2410 (Willamette Valley-Puget Trough), US Fish and Wildlife Service, Division of Ecological Services, Portland, OR.

US Fish and Wildlife Service. 1981. Standards for the development of habitat suitability index models. 103 ESM. US Fish and Wildlife Service, Washington, DC.

US Fish and Wildlife Service. 1980. Habitat Evaluation Procedure (HEP) Manual. 102 ESM. US Fish and Wildlife Service, Washington, DC.

Van Denburgh, A.S. and J.F. Santos. 1965. Ground water in Washington: its chemical and physical quality. State of Washington Department of Conservation, Water Supply Bulletin No. 24.

Varis, O., S. Kuikka, and A. Taskinen. 1994. Modeling for water quality decisions: uncertainty and subjectivity in information, in objectives, and in model structure. Ecological Modeling 74:91-101.

Verner, J., M. L. Morrison, and C. J. Ralph, eds. 1986. Wildlife 2000:

Voigts, D. K. 1976. Aquatic invertebrate abundance in relation to changing marsh vegetation. The American Midland Naturalist. 95:313-323.

Walker, I. R., C. H. Fernando, and C. G. Paterson. 1985. Associations of *chironomidae* (Diptera) of shallow, acid, humic lakes and bog pools in Atlantic Canada, and a comparison with an earlier paleological investigation. Hydrobiologia 120:11-22.

Washington State Department of Ecology. 1993. Washington State Wetlands Rating System - Western Washington. Second Edition. Publication #93-74. Olympia, WA, .

Weller, M.W. 1990. Waterfowl management techniques for wetland enhancement, restoration, and creation useful in mitigation procedures. Pp.517-528 in Kusler, J.A. and M.E. Kentula (eds.) Wetland creation and restoration: the status of the science. Island Press Washington DC.

Weller, M.W. and C.S. Spatcher. 1965. Role of habitat in the distribution and abundance of marsh birds. Iowa Agricultural Home Economics Experiment Station, Special Report No. 43.

Wiggins, G. B., R. J. Mackay, and I. M. Smith. 1980. Evolutionary and ecological strategies of animals in annual temporary pools. Archiv fur Hydrobiologie:99-206.

Wilcox, D.A. and J.E. Meeker. 1992. Implications for faunal habitat related to altered macrophyte structure in regulated lakes in northern Minnesota. Wetlands 12: 192-203.

Willard, D.E. 1977. The feeding ecology and behavior of five species of herons in southeastern New Jersey. Condor 79:462-470.

Wise, M.H., I. Linn, and C. Kennedy. 1981. A comparison of the feeding biology of mink (*Mustela vison*) and otter (*Lutra lutra*). J. Zool. Lond. 195:181-213.

Zeigler, R. 1992. Buffer Needs of Wetland Wildlife. Washington Department of Wildlife, Olympia, WA.

Glossary

Adsorption – The attraction and adhesion of a layer of ions from an aqueous solution to the solid mineral surface with which it is in contact.

Aerobic – A situation in which molecular oxygen is a part of the environment.

Agriculture (land use) – Field or pasture used for grazing or cultivation of crops.

Anadromous – Pertaining to fish that spend most of their life in salt water but enter fresh water to spawn.

Anaerobic – A situation in which molecular oxygen is absent (or effectively so) from the environment.

Anoxic – A situation devoid of molecular oxygen.

Anthropogenic – Caused by human action.

Aquatic bed class – Any area of open water covered by plants that grow principally on or below the water surface for most of the growing season in most years. Species are non-persistent and include submerged or floating-leaved rooted vascular plants, submerged mosses, and algae.

Areal cover – A measure of dominance that defines the degree to which aboveground portions of plants (not limited to those rooted in a sample plot) cover the ground surface. It is possible for total areal cover in a community to exceed 100 percent because: a) most plant communities consist of two or more vegetative strata; b) areal cover is estimated by vegetative layer; and c) foliage within a single layer may overlap.

Assessment Team – Interdisciplinary teams that helped develop the models and methods. One team focused on wetlands of the riverine class, and the other team worked on wetlands of the depressional class.

Assessment unit (AU) – The wetland area in which the level of performance of various functions is being assessed. An assessment unit may be an entire wetland or parts of a wetland.

Biodiversity – The number and relative abundance of all species within a given area.

Browse – Tender parts of woody vegetation eaten by animals especially beaver.

Calibration – The process undertaken by the Assessment Teams of developing the numeric scaling for each variable for each function. This was done using data from the reference sites in each wetland subclass.

Canopy stratum – The highest layer of vegetation in an assemblage, typically consisting of large trees that may extend over any of the other four strata.

Canopy cover – The degree to which the foliage of the canopy (highest vegetation layer in an assemblage) blocks sunlight or obscures the sky.

Cation – An atom or group of atoms with a positive charge.

Channel – A distinct linear depression with identifiable bank edges that have been shaped by flowing water and have a definable outlet. Includes man-made ditches and grassy swales that may have intermittent flows.

Chironomid – A member of the family Chironomidae (midges); a cosmopolitan family of small delicate flies (Diptera) that swarm in vast numbers in damp habitats.

Class – A taxonomic unit is a classification scheme. In the Cowardin et al. (1979) classification of wetlands it refers to the highest taxonomic unit below the Subsystem level. In the HGM system it is the highest taxonomic unit.

Clear-cut logging (land use) – Areas where all mature trees have been removed within 5 years of the time of the site visit. Saplings should not be more than 2 m tall.

Co-dominance – Species that cover between 20-50% of the ground surface.

Commensal – A relationship between two organisms in which one lives in or on another species that is neither harmed nor benefited by its presence.

Control structure – An artificial feature that is used to regulate the flow of water.

Denitrification – The biological conversion of nitrate nitrogen to nitrogen gas by microbes in anaerobic conditions.

Depressional wetland – Depressional wetlands occur in topographic depressions that exhibit closed contour interval(s) on three sides and elevations that are lower than the surrounding landscape.

Detritivores – An organism that feeds on dead organic matter.

Diameter at breast height (dbh) – the diameter of a tree, measured 4.5 feet above the ground on the uphill side of the tree.

Dike – An artificial embankment constructed to hold water to prevent flooding of adjacent land.

Edge – The boundary where habitats meet or where successional stages of plant communities come together.

Emergent Class – Any area covered by erect, persistent, herbaceous plants excluding mosses and lichens, that provides at least 30% areal cover to the upper most vegetation layer.

Emergent Plant – Plants that are rooted in shallow water but have photosynthesizing structures above the water's surface.

Epiphytic – Those plants that grow on another plant for support and anchorage rather than for water or nutrient supply.

Eutrophication – The process of enrichment with nutrients, leading to increased production of organic matter.

Field Team – Teams of volunteers from several resource agencies, trained in the methods for collecting data, that collected data at reference sites on 60 different environmental characteristics. These data were used to calibrate the models. Field Teams also evaluated the relative level of potential performance or habitat suitability for each function at each reference site.

Forested Class – A Cowardin vegetation class where woody vegetation over 6 m (20 ft.) tall comprises at least 30% of the areal cover.

Frequent – Occurring at least once every two years.

Functions – The physical, chemical, and biological processes or attributes of a wetland.

Groundwater – That portion of the water below the ground surface that is under greater pressure than atmospheric pressure.

Guild – A group of species that have similar ecological resource requirements and foraging strategies, and as result, have similar roles in a community.

Herbaceous stratum – A layer of non-woody vegetation, usually less than 2 m (6 ft.) tall.

High density residential (land use) – Areas with apartments, town houses, and individual homes where there is more than one residence per 0.4 hectares (1 acre).

Hydrogeomorphic – Categorization of wetlands based upon geomorphic setting, water source and transport, and hydrodynamics.

Hydroperiod – The depth, duration, and frequency of flooding or saturation of soils on a seasonal basis.

Hydrostatic process – The process by which fluids are brought to rest under pressure.

Hyporheic zone – The subsurface region of streams and rivers that exchanges water with the surface.

Index – a numerical result that represents the deviation of performance of function from those wetlands judged to be the highest performers for each individual function sites in that subclass and domain.

Indicator – easily observed characteristics that are correlated with quantitative or qualitative observations of an environmental variable.

Interflow – The precipitation that infiltrates into the soil and moves laterally under the surface until intercepted by a stream channel or until it resurfaces downslope of its point of infiltration.

Interspersion – The degree of intermixing of different cover types, regardless of the number of types or their relative proportions.

Inundation – A rising and spreading of water over land not usually submerged; flooding.

Large woody debris (LWD) – Dead or dying woody material on the AU surface, or in water, that is at least 2 m (6.6 ft.) long and a minimum of 10 cm (4 in.) in diameter at the widest part.

Lentic – An adjective indicating a connection to standing water of one kind or another. Examples are lakes and ponds.

Low density residential (land use) – Individual homes on parcels of 0.4 hectares (1 acre) or more.

Macrophyte – Plants that can be seen with the unaided eye. This includes all vascular plant species and mosses (e.g., Sphagnum spp.), as well as large algae (e.g. Chara spp.).

Method – Collection of models for a specific subclass

Model – Equation used to estimate the relative level of performance of a specific function for a specific subclass.

Mosaic – Made up of many different interspersed elements; used in regard to vegetation or wetland types.

Nitrification – The process of converting ammonia into nitrites or nitrates, inorganic forms of nitrogen that can be assimilated by plants.

Outlet – The point at which a body of water discharges to another body of water.

Outlet, severely constricted – Those outlets that are small or heavily incised, narrow channels anchored in steep slopes.

Outlet, moderately constricted – When the outlet is small or narrow enough to cause flood water flowing through the AU to be held back.

Outlet, not channelized – Those outlets, only applicable in wetlands of the riverine impounding subclass, where surface water does not leave the wetland through any type of channel or culvert; rather it leaves by sheetflow over a berm, dike, or sheetflow through vegetated areas.

Outlet, unconstricted – When the outlet allows water to flow out of the AU across a wide distance. Large floodplain wetlands often have no clear outlets and water leaves by sheetflow. In such cases, the outlet is considered unconstricted.

Oxic – A situation when molecular oxygen is present.

pH – The negative logarithm of hydrogen ion concentrations. A measure of the relative intensity of acidity or alkalinity of water, with the neutral point at 7.0. Values lower than 7.0 indicate the presence of acids; above 7.0 the presence of alkali.

Redox – Referring to mineral changes in response to oxidation and reduction reactions.

Reference domain – All wetlands within a defined geographic region that belong to a single hydrogeomorphic subclass.

Reference standard wetlands – Subset of reference wetlands that establish the characteristics that must be present in a wetland for it to score the highest for a function.

Reference wetlands – A group of wetlands within the reference domain that encompass the known variation of a hydrogeomorphic subclass.

Riparian corridor – An area containing a stream or river that connect the AU to other wetlands or areas of permanent or seasonal water. It is characterized by the presence of vegetation that tolerates moist conditions. It must contain an intermittent or permanent stream or river.

Salmonid – Those fishes in the family Salmonidae, including trout, salmon, char and whitefish.

Scrub-shrub Class – A Cowardin vegetation class where woody vegetation less than 6 m (20 ft.) tall provides at least 30% cover, and is the upper most vegetation layer.

Sediment – Material suspended in flowing water which ultimately settles to the bottom after the water loses velocity.

Seral – The developmental or transitional stages of ecological succession not including the climax community.

Sheetflow – Runoff water occurring after a rain or snow event that flows over the ground surface.

Shrub stratum – A layer of woody vegetation taller than 2 m (6 ft.) consisting of shrubs, or young trees. Rarely exceeds 6 m (20 ft.) in height.

Sorption – A general term including processes such as absorption and adsorption; absorption of a gas by a solid.

Species richness – The total number of species in a community or assemblage.

Sphagnum – A genus of grayish-green moss growing in dense layers in bogs that eventually forms peat.

Statewide Technical Committee (SWTC) – A technical committee chosen for its expertise in wetland function assessment. The SWTC guides the technical components of the Washington State Function Assessment Project statewide.

Strata – A layer of vegetation covering at least 20% of the ground within the boundary of its plant assemblage, and that is rooted in the AU. There are six potential strata: mosses and other ground cover; herbs; shrub; sub-canopy; canopy; and vines.

Streamflow – The discharge that occurs in a natural channel.

Storage, dead – The volume of water in a reservoir below the sill of the lowest outlet.

Storage, live – The volume of water in a reservoir exclusive of dead storage capacity.

Stormflow – The volume of runoff, groundwater flow or streamflow resulting from a storm event. A quantity discharged in excess of base flow conditions.

Subclass – The taxonomic subdivision just below the class level (see class)..

Sub-canopy stratum – A layer of young or small trees ranging from 6-12 m (20-40 ft.) growing under a canopy.

Symbiotic – A relationship between two organisms or populations, usually mutually beneficial.

Tannin – Any one of a group of soluble astringent complex phenolic substances that are widely distributed in plants.

Taxa – A category in the biological system of arranging plants and animals in related groups, such as class, family, or phylum.

Trophic level – A stage in a food web occupied by organisms that feed on the same general type of food.

Undeveloped areas (land use) – Shrubland (areas of shrubs and grassland not cut or grazed), other wetlands, and open water outside the AU.

Undeveloped forest (land use) – Areas of managed and unmanaged forests not including clear-cut areas.

Upland – As used herein, any area that does not qualify as a wetland because the associated hydrologic regime is not sufficiently wet to elicit development of vegetation, soils, and/or hydrologic characteristics associated with wetlands.

Upland islands – Islands larger than 10 m^2 (1000 ft^2) and surrounded my at least 30 m (100 ft.) of open water deeper than 1 m (3 ft.).

Urban/commercial (land use) – Areas where over 50% of the area is in urban or commercial uses.

Values – Wetland processes, characteristics, or attributes that are considered to benefit society.

Variable – Measurable components of functions that are used to build the models for each function.

Vine stratum – A vegetation layer of creeping or climbing vines that can range in size from <1 m high to several meters high.

Watershed – The boundary of an area from which water drains to a single point; in a natural basin, the area contributing flow to a given point on a stream.

Wetlands – Those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas (40 CFR 230.3 and CFR 328.3).

List of Acronyms

AU	Assessment Unit
Corps	US Army Corps of Engineers
dbh	Diameter at breast height
Ecology	Washington State Department of Ecology, also “WDOE” (in publication references)
EM	Emergent
FO	Forested
GIS	Geographic Information System
HEP	Habitat Evaluation Procedure
HGM	Hydrogeomorphic
IVA	Indicator Value Assessment
IWRB	Interagency Wetland Review Board
LWD	Large woody debris
NRCS	Natural Resource Conservation Service
NWI	National Wetlands Inventory
PHS	Priority Habitats and Species
SS	Scrub-shrub
SWTC	Statewide Technical Committee
USFWS	US Fish and Wildlife Service
WDFW	Washington Department of Fish and Wildlife
WDOE	Washington Department of Ecology, also “Ecology” in text
WET	Wetland Evaluation Technique
WFAP	Wetland Function Assessment Project

Appendix A: Members of the Project's Committees and Teams

Members of the Statewide Technical Committee

Name	Organization
Ken Brunner	US Army Corps of Engineers
Dr. Sarah Cooke	Cooke Scientific Services
Joel Fruedenthal	Clallam County
Robert Fuerstenberg	King County Surface Water Management
Dr. Tom Hruby	Washington State Department of Ecology
Dr. Chuck Klimas	Klimas and Associates
Ivan Lines	US Natural Resources Conservation Service (retired)
Andy McMillan	Washington State Department of Ecology
Charles Newling	Wetland Training Institute
Dr. Ken Raedeke	Raedeke Associates
Dyanne Sheldon	Sheldon and Associates
Curtis Tanner	US Fish and Wildlife Service
Paul Wagner	Washington State Department of Transportation
Dr. Fred Weinmann	US Environmental Protection Agency (retired)
Bob Zeigler	Washington Department of Fish and Wildlife

Implementation Committee

Members and Invited Guests

Name	Organization
Peter Antolin	Washington State Office of Financial Management
Jerry Alb	Washington State Department of Transportation
Jim Anderson	Northwest Indian Fisheries Commission
Amy Bell	Washington State Department of Natural Resources
Peter Birch	Washington Department of Fish and Wildlife
Mason Bowles	King County
Nancy Brennon-Dubbs	US Fish and Wildlife Service
Ginny Broadhurst	Puget Sound Water Quality Authority
Gary Cooper	Thurston County
Linda Crerar	Washington State Department of Ecology
Lee Daneker	US Environmental Protection Agency
Duane Fagregren	Puget Sound Action Team
Lee Faulconer	Washington State Department of Agriculture
Dana Field	Oregon Division of State Lands
Joel Freudenthal	Clallum County
Tim Dring	Natural Resource Conservation Service
Jim Fox	Interagency Committee for Outdoor Recreation
Eric Johnson	Washington Pubic Ports Association
Karla Kluge	City of Tacoma
Ross Lahren	Natural Resource Conservation Service
Cathy Lear	Hoh Tribe
Patsy Martin	Washington Association of Public Ports
Paul Meehan-Martin	Snohomish County
Steve Meyer	Washington State Conservation Commission
Lloyd Moody	Washington State Governor's Office
Tom Mueller	US Army Corps of Engineers
Paul Parker	Washington State Association of Counties
Alisa Ralph	US Fish and Wildlife Service
Ralph Rogers	US Environmental Protection Agency
Carl Samuelson	WA Department of Fish and Wildlife
Ron Shavlik	Natural Resources Conservation Service
Randy Sleight	Washington State Association of Counties, Snohomish County
Geoffrey Thomas	Lewis County
Gary Voerman	US Environmental Protection Agency
Paul Wagner	Washington State Department of Transportation
Steve Wells	WA State Department of Community Trade, Economics and Development
Dave Williams	Association of Washington Cities
Bob Zeigler	Washington Department of Fish and Wildlife

Members of the Riverine Assessment Team for the Lowlands Western Washington

Name	Organization
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Members of the Depressional Assessment Team for the Lowlands Western Washington

Name	Organization
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Dr. Tom Hruby	Washington State Department of Ecology
Dr. Klaus Richter	King County
Dr. Lorin Reinelt	City of Issaquah

Appendix B: Description and Geographic Extent of the Lowlands of Western Washington

Description and Geographic Extent of the Lowlands of Western Washington

The geographic extent of lowland western Washington *for the purposes of these methods* are based on the Ecoregions of the Pacific Northwest as defined by Omernik (1986). Portions of three ecoregions from Omernik are included: Coast Range, Puget Lowlands and Willamette Valley (Labeled 1, 2, and 3 respectively on attached figure). Characteristics of these ecoregions are detailed below.

Coast Range: This area extends from the Pacific Coast east to the Puget Lowland ecoregion exclusive of the higher elevations of the Olympic Mountains. It includes large portions of Clallam, Jefferson, and Grays Harbor counties and all of the Pacific and Wahkiakum Counties.

Land form: Coastal lowlands, hills and low mountains to an elevation of about 2000 ft.
Potential natural vegetation: Spruce/cedar/hemlock; cedar/hemlock; Douglas fir.
Soils: Udic soils of high rainfall areas.

> **Note:** The **depressional interdunal wetlands of the lowlands of western Washington,** that occur in the Coast Range**, are not being modeled at this time.** The area in which they occur is, therefore, not shown in the geographic range map on the following page.

Puget Lowlands: This area is from the eastern boundary of the Coast Range ecoregion to the western edge of the Cascade ecoregion. Elevations approach 2000 feet in the north and 2500 feet in the south. All or portions of the 14 counties between Whatcom County in the north and Clark County in the south are included.

Land form: Tablelands with moderate relief, plains with hills or lower mountains.
Potential natural vegetation: western red cedar/western hemlock/Douglas fir.
Soils: Alfisols, inceptisols, mollisols, spodosols, and vertisols.

Willamette Valley: In Washington this includes only the extreme northern tip of the ecoregion. Most of Clark County is in this ecoregion. The region also extends along the Columbia River,at low elevations, east to White Salmon.

Land form: Plains with hills or open hills to an elevation of about 2000 feet.
Potential natural vegetation: Western red cedar/western hemlock/Douglas fir; mosaic of Oregon white oak woodlands and western red cedar/western hemlock/Douglas fir.
Soils: Xeric mollisols, vertisols, and alfisols.

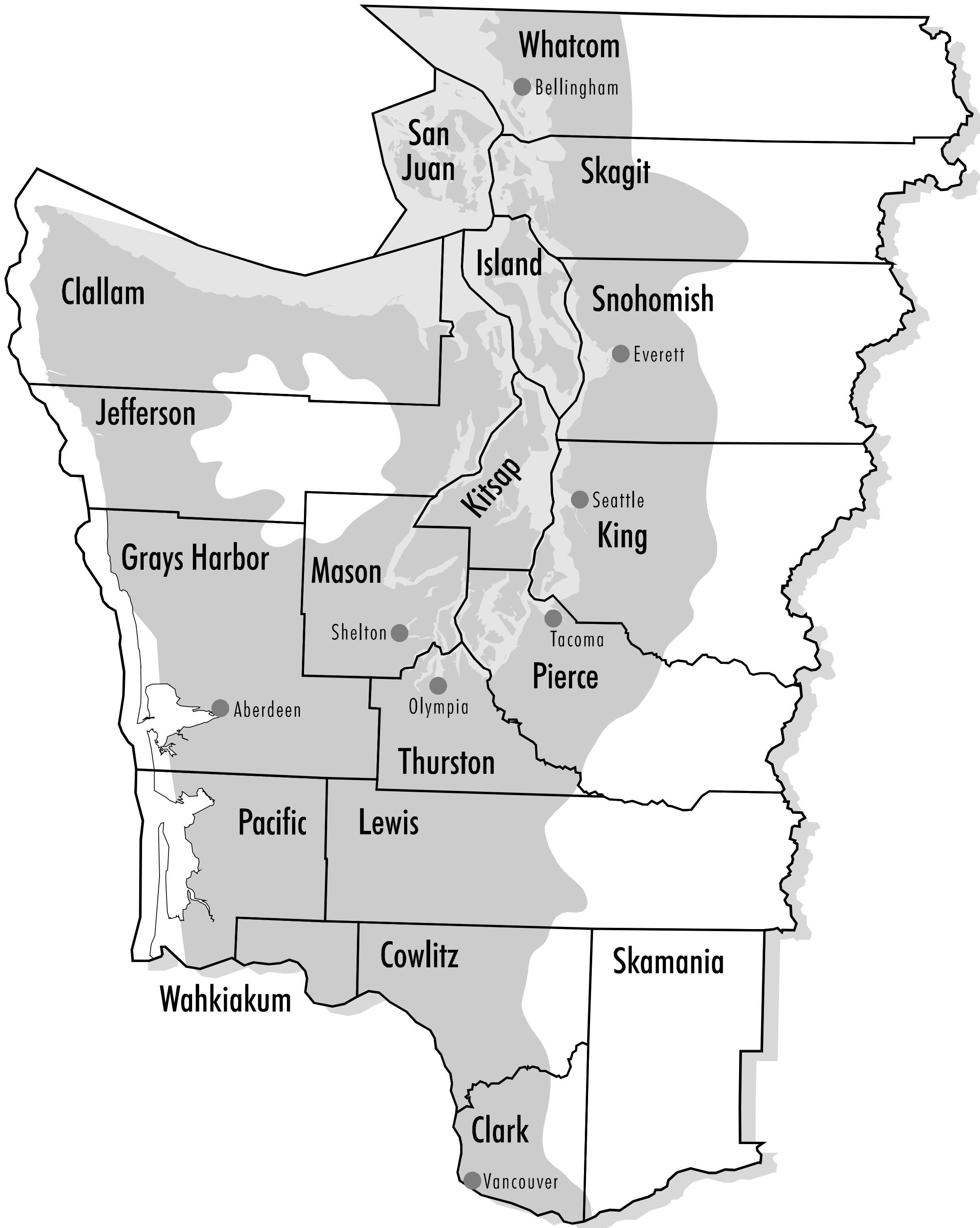

Figure 2: Lowlands of Western Washington – Hydrogeomorphic Region for Assessing Wetland Functions

Appendix C: Profiles of Wetland Classes and Subclasses in the Lowlands of Western Washington

Profiles of Wetland Classes and Subclasses in the Lowlands of Western Washington

Class: Riverine

Riverine wetlands occur in floodplains and riparian corridors in association with stream or river channels. They lie in the active floodplain of a river, and have important hydrologic links to the water dynamics of the river or stream. The distinguishing characteristic of riverine wetlands in Washington is that they are frequently flooded by overbank flow from the stream or river. The flooding waters are a major environmental factor that structure the ecosystem in these wetlands. Wetlands that lie in floodplains but are not frequently flooded are not classified as riverine.

Surface and shallow subsurface water movement in most riverine wetlands is from the valley sides toward the stream channel, from the stream channel toward the adjacent floodplain and downstream during overbank events. Additional water sources may be groundwater discharge, overland flow from adjacent uplands and tributaries, and precipitation.

Water leaves riverine wetlands by surface flow returning to the river or stream channel after flooding or a rain event. The wetlands also may lose subsurface water by subsurface discharge to the channel called interflow (movement of water to shallow groundwater through infiltration), and evapotranspiration.

Many riverine wetlands are associated with rivers that are very dynamic. Their proximity to the river facilitates the rapid transfer of floodwaters in and out of the wetland, and the import and export of sediments. These wetlands are subject to frequent flood disturbances that may reset the “successional clock”. The dominant vegetation in these wetlands may be representative of any of the seral stages possible; from early successional, emergent species, to late successional forest species.

Riverine wetlands are often replaced by depressional or slope wetlands near the headwaters of streams and rivers, where the channel (bed) and bank disappear, and overbank flooding grades into surface or groundwater inundation. In headwaters, the dominant source of water becomes surface runoff or groundwater seepage. For the purposes of classifying wetlands, wetlands that show evidence of frequent overbank flooding, even if from an intermittent stream, are considered riverine.

Riverine wetlands normally intergrade with tidal fringe wetlands near the mouths of rivers. The interface with tidal fringe occurs where the dominant hydrodynamics change to bi-directional tidal flows (Brinson et al 1995). This interface has been significantly modified in western Washington by diking. Many wetlands that were once freshwater tidal (a subclass of tidal fringe in Washington) are now either riverine or depressional (depending on the frequency of flooding).

Riverine wetlands normally extend perpendicular from the stream or river channel to the edge of the area that is frequently flooded (also known as active channel). Wetlands in large floodplains that are found outside of frequently flooded areas, and that are in landscapes with great topographic relief and steep hydrostatic gradients, may function more like slope or depressional wetlands because the water regime is dominated by groundwater sources (see discussion in Brinson et al. 1995).

Field Characteristics for Riverine Wetlands in Washington State:

The operative characteristic of riverine wetlands in Washington is that of being “frequently flooded” by overbank flows. The Assessment Teams and SWTC, however, decided that this characteristic could only be determined from field indicators. The water regimes of wetlands in Washington have enough variability between dry and wet years that a frequency of flooding (e.g. flooded at least once every two years) could not be used. The following are some field indicators that are to be used to classify a wetland as riverine:

- Scour marks are common
- Recent sediment deposition
- Vegetation bent in one direction or damaged
- Soils with alternating deposits
- Flood marks on vegetation along the bank edge

Subclass: Riverine Flow-through

Riverine flow-through wetlands are those that do not retain surface water significantly longer than the duration of a flood event. Water tends to flow through the wetland rather than pond in the wetland. Usually the water does not remain in the wetland more than several days after the surrounding landscape is drained. Soil saturation, however, may be maintained by groundwater seepage from valley walls. Flow-through wetlands usually have evidence of active erosion and deposition and have a dynamic, fluctuating hydroperiod that closely matches that of the stream or river.

The wetlands in this subclass tend to be found in, or adjacent to, the active channel of a river or larger stream. They may be the vegetated bars in the active channel or they may form on recent alluvial deposits along the sides of the channel or within the channel.

Field characteristics of Riverine Flow-through Wetlands for Western Washington:

- Contains a less dense herbaceous understory, that commonly includes stinging nettle *(Urtica dioica)*
- Contains deciduous shrubs and trees (conifers are less likely)
- The soils are more coarse and have higher mineral content than those found in the impounding subclass
- The vegetation tends to be less diverse than in the impounding subclass

Subclass: Riverine Impounding

Riverine impounding wetlands are those that retain surface water significantly longer than the duration of a flood event. Riverine impounding wetlands tend to hold water for more than a week after a flood event. These wetlands are found within a topographic depression on the valley floor or in areas where natural or man-made barriers to downstream flow occur. The depressions may be filled with sediments or organic deposits. The critical characteristic, however, is that these wetlands retain floodwaters after an event longer than the surrounding landscape. Riverine impounding wetlands may have no outlet, or a constricted outlet, and have a hydroperiod that is less dynamic than that found in the adjacent stream, river, or “flow-through” wetland in the same valley.

Most riverine impounding wetlands are in the less dynamic parts of the floodplain; often on floodplain terraces or in old oxbows. Many may have peat accumulations that are isolated from the usual riverine processes, and they are subjected to long duration of saturation from surface or groundwater sources. Riverine processes will dominate only during the flooding event, though the groundwater levels may be controlled by water levels in the hyporheic zone through hydrostatic processes.

Some wetlands in the lowlands of western Washington fall into this subclass because dikes or roads have reduced their surface water connections. At one time, these wetlands did not retain floodwaters longer than the actual flooding event, but do so now because of a blockage.

Field characteristics of Riverine Impounding wetlands for western Washington:

- More herbaceous understory, commonly containing skunk cabbage *(Lysichiton americanum)*
- Aquatic vascular species are frequently present
- If there is a forested component, it may contain conifers
- Contains finer soils which may have a higher organic content
- Vegetation tends to be more diverse than in riverine flow-through wetlands

Class: Depressional

Depressional wetlands occur in topographic depressions that exhibit closed contour interval(s) on three sides and elevations that are lower than the surrounding landscape. The shape of depressional wetlands vary, but in all cases, the movement of surface water and shallow subsurface water from at least three directions in the surrounding landscape is toward the point of lowest elevation in the depression. Depressional wetlands may be isolated with no surface water inflow or outflow through a defined channel, or they may have permanent or intermittent, surface water inflow or outflow in defined channels, that connects them to other surface waters or other wetlands. Streams draining into a wetland may modify the topographic contours of the depression where they enter or exit the wetland. Depressional wetlands with channels or streams differ from riverine wetlands in that their ecosystem is not significantly modified by overbank flooding events from a stream or river. Headwater wetlands would be classified as depressional or slope because overbank flooding is not a major ecological factor.

Depressional wetlands may lose water through intermittent or perennial drainage from an outlet, by evapotranspiration, and flow into the groundwater at times when they are not receiving discharge from groundwater.

The outflow and closed subclasses have very similar positions in the landscape that do not warrant separate geomorphic profiles. Differences between the subclasses are based on the functions they perform. The geomorphic characteristics of depressional wetlands in lowland western Washington are as follows:

1. Depressional wetlands in lowland western Washington are found in the following geomorphic settings; 1) former kettleholes left by receding glaciers, 2) depressions on top of clay lenses in glacial outwash, such as the area between Olympia and the Chehalis River, 3) headwaters of lowland streams, 4) alluvial terraces above the existing floodplains, 5) depressions in glacial till, and 6) in depressions in the flood plains of major rivers that have become isolated from frequent flood events.
2. Many depressional wetlands have well developed peat deposits because the outflow, if it exists, is above the base of the depression. Thus, organic matter will tend to collect.

Field characteristics for Depressional wetlands in western Washington :

Depressional wetlands in the lowlands of western Washington lie in topographic depressions where the slope on at least three sides above the wetland is greater than 1%, and that are not within the active floodplain of a stream or river. There may be a stream going through the wetland, but if so, it is not the major source of physical energy to the system.

The topographic depressions that characterize the position of this class in the landscape can be very small with only slight differences in elevation between the wetland and surrounding uplands. Some depressional wetlands are found on relatively flat surfaces, often in pastures. They are formed in depressions that exist in soils with low permeability such as glacial till.

Very small wetlands found in surface depressions with only 1-3 feet of topographic relief may be difficult to classify. If such wetlands form a mosaic on a landscape that is flat it may be more appropriate to classify them as a single wetland in the flats class if the only source of water to the wetland is precipitation. If the wetland receives a significant amount of its water from a surrounding contributing basin, however slight the topographic relief, it would be classified as a depressional wetland. A wetland classified as a flat, on the other hand, receives its water by direct precipitation only from the area within the wetland.

Subclass: ***Outflow***

Depressional outflow wetlands are those that have a surface water outflow to a stream or river. Inflow may be from surface water flowing down from the surrounding topographic relief, from an intermittent or permanent stream(s), or from groundwater.

Subclass: ***Closed***

Depressional closed wetlands are those that have no surface water outflow to channels, streams, or rivers. Depressional closed wetlands may have surface water inflow but no outflow through a defined channel.

CLASS: Slope

Slope wetlands occur on hill or valley slopes. Elevation gradients may range from steep hillsides to slight slopes. Principal water sources are usually groundwater seepage and precipitation. Slope wetlands may occur in nearly flat landscapes if groundwater discharge is a dominant source of water and there is flow in one direction. The movement of surface and shallow subsurface water is perpendicular to topographic contour lines. Slope wetlands are distinguished from the riverine wetland class by the lack of a defined topographic valley with observable features of bed and bank. Slope wetlands may develop channels but the channels serve only to convey water away from the slope wetland.

Field characteristics for Slope wetlands in western Washington:

Slope wetlands in Washington are found on hillsides or at the edge of hill where they grade into a river valley. They are identified by the fact that they are: 1) on a slope, even if very gradual), 2) lacking closed contours and cannot store surface water, and 3) without obvious surface water inflows such as streams or channels.

Note: Subclasses for this class of wetlands have not yet been identified.

CLASS: Lacustrine Fringe

Lacustrine fringe wetlands in western Washington occur at the margin of topographic depressions in which surface water is greater than 8 ha (20 acres) and greater than 2 meters deep (3 meters in eastern Washington). They are found along the edges of bodies of water such as lakes. The dominant surface water movement in lacustrine fringe wetlands has a bi-directional horizontal component due to winds or currents, but there may also be a corresponding vertical component resulting from seiches, wind, or seasonal water fluctuations.

Field characteristics for Lacustrine Fringe wetlands in western Washington:

Lacustrine fringe wetlands are those adjacent to bodies of freshwater that are at least two meters deep and more than 8 hectares (ha) is size (20 acres). In general, the deep water has to represent at least 30% of the area of open water. Some wetlands may be adjacent to rivers that are more than two meters deep but these would be classified as riverine because the flow tends to be in one direction and the wetland is subject to frequent overbank flooding.

Note: Subclasses for lacustrine fringe wetlands have not yet been identified.

CLASS: Tidal Fringe

Tidal fringe wetlands occur on continental margins where marine waters are greater than 2 meters deep. They are found along the coasts and in river mouths to the extent of tidal influence. The dominant source of water is from the ocean or river. The unifying characteristic of this class is the hydrodynamics. All tidal fringe wetlands have water flows dominated by tidal influences, and water depths controlled by tidal cycles.

Subclass: Tidal Saltwater Fringe

Tidal fringe wetlands in which the dominant water flows have salinity rates higher than 0.5 parts per thousand.

Subclass: Tidal Freshwater Fringe

Tidal fringe wetlands in which the dominant water flows are tidal but freshwater, with salinity rates below 0.5 parts per thousand.

CLASS: Flats

Flats wetlands occur in topographically flat areas that are hydrologically isolated from surrounding groundwater or surface water. The main source of water in these wetlands is precipitation. They receive virtually no groundwater discharge. This characteristic distinguishes them from depressional and slope wetlands.

Note: No subclasses are proposed for the flats class in western Washington.

References Cited:

Brinson, M.M., F.R. Hauer, L.C. Lee, W.L. Nutter, R.D. Rheinhardt, R.D. Smith, and D. Whigham. 1995. Guidebook for application of hydrogeomorphic assessments to riverine wetlands. DRAFT U.S. Army Engineer Waterways Experiment Station Wetlands Research Program Technical Report WRP DE-11.

Appendix D: Comparison of the National Hydrogeomorphic and the Washington Approaches to Choosing Reference Standard Wetlands

Comparison of the National Hydrogeomorphic and the Washington Approaches to Choosing Reference Standard Wetlands

This appendix compares the approach to choosing reference standard wetlands under the Hydrogeomorphic (HGM) Approach being developed by the US Army Corps of Engineers (Corps) at the national level and the HGM-based approach used by the Washington State Wetland Function Assessment Project (WFAP). It also explains potential management implications of the different approaches.

Background

The Corps has been the lead agency working on developing a national HGM Approach to assessing wetland functions. They have developed and published documents, conducted training workshops and funded the development of regional methods. At present, however, there are no final drafts of these assessment methods available for use in the field.

The WFAP chose to follow the national HGM Approach but also decided to make some changes to meet wetland management needs in Washington. The Statewide Technical Committee (SWTC) that is responsible for steering the project identified potential changes early in the process but decided to wait until field data collection and model calibration were completed before making any final decisions. The SWTC ultimately decided to make a substantial change in the way reference standard wetlands are selected. Both the national HGM Approach and the WFAP approaches to choosing reference standards are scientifically supportable. However, information about wetland functions derived from the two approaches are different and serve different purposes with respect to making wetland management decisions. Outlined below are the primary differences to choosing reference standard wetlands between the two approaches, followed by the management implications of the differences.

How the Two Approaches Differ

The primary difference between the two approaches is *what* they assess. While both produce results in terms of “functions,” there is a distinct difference in how they define and assess functions.

The national HGM Approach assesses the *condition* of a wetland relative to the “least altered” examples of that wetland type. The underlying assumption is that those wetlands that are the least altered examples in the least altered watersheds (the reference standard wetlands) are performing the full suite of *appropriate* functions at the highest *sustainable* level. This means that the characteristics found in the wetlands that have been subject to the least amount of human disturbance are the characteristics that set the standard for the highest level of performance for *all* functions. This approach really assesses the relative “naturalness,” or condition, of the wetland and expresses it in terms of functions. Functional capacity is used as the “currency” to represent the *deviation* of the assessed wetland from the least altered conditions.

If a wetland being assessed has different characteristics than those found in the least altered ones in the reference set then it will score lower - regardless of whether the wetland is actually performing a particular function at a higher level (see example below). The assumption is that any increase in performance of that function is “not sustainable” because it is the result of human disturbance. Likewise this approach assumes that the level of functioning found in wetlands subject to the least amount of anthropogenic disturbance is sustainable.

The WFAP Approach assesses the *relative level of performance* of individual functions based on specific environmental characteristics. The assumption underlying this approach is that the highest level of performance for a given wetland function will occur when specific environmental conditions are met, regardless of whether those conditions are the result of human disturbance. Thus, this approach assesses the relative level of performance of *individual* functions and does not attempt to assess “naturalness,” wetland condition or whether the performance of functions is sustainable or not.

Concerns Regarding Use of the National HGM Approach

The primary concern with the national HGM Approach is that it seems to be best suited for use in landscapes that have not been subject to long-term human alterations. The national HGM Approach seems to make sense for federal land managers who have some degree of control over large portions of watersheds and who may be in a position to attempt to restore the wetland ecosystems to a relatively natural condition. However, most of our wetland management decisions in Washington occur in areas with long-term *and ongoing* human alterations and it is impossible to determine which wetland systems and functions are "sustainable" in this context.

Cost Implications

One of the most serious consequences of using the national HGM Approach is that it is much more expensive. Data collection has demonstrated that there is great variability in wetland characteristics even when one looks only at the least altered example of a wetland type. This variability results from different levels of *natural* disturbance (wind, flood, fire, beaver, etc.) and the normal heterogeneity found in natural systems. If one attempts to use the least altered examples of riverine flow-through wetlands for western Washington to set the reference standards, the range of variability of the environmental characteristics (vegetation, soils, basin size, etc.) is so great that most wetlands of that type would fall within the range of variability. This means that most wetlands that would be assessed would score a 10. The only way to reduce the range of variability to an acceptable level is to reduce the size of the region (reference domain) or subdivide the wetland type into more subclasses. This means more methods are needed to cover the same geographic area and *this adds significantly to the cost.* To divide Washington into regions and classes that would work for the national HGM Approach would mean developing many more methods than are currently being proposed.

Management Implications

There are several consequences of using the national HGM Approach that have serious implications for wetlands management.

1. The national HGM Approach assumes that the least altered wetlands are performing the "appropriate" functions for that wetland type. This means that other, potentially important functions, that may be performed by more altered wetlands will not even be assessed. For example, in western Washington, the least altered examples of riverine wetlands are forested. These wetlands are not providing habitat for most waterfowl, and shorebirds. However, many of our riverine wetlands have been subjected to extensive agricultural practices that have removed most of the woody vegetation. This, combined with the fact that most of our tidal wetlands have been filled, means that many waterfowl, shorebird and raptor species depend on these agricultural wetlands for habitat. Under the national HGM Approach, these important habitat functions would not even be assessed since they do not occur in the least altered (e.g. forested) wetland types.
2. Wetlands found in more highly altered landscapes (urban and agricultural areas) will score lower for most functions regardless of whether they perform certain functions at a high level. For example, if a wetland has been altered by the addition of an outlet structure that impounds more water, then it would score lower for flood-related functions because it doesn't have the characteristics of a "least altered" wetland, even if it is, in fact, performing that function at a *higher* level. Authors of the national HGM Approach would argue that it shouldn't score higher because the higher level of performance is not "sustainable." However, these systems are relatively stable and not likely to change or disappear soon and wetland managers are faced with making decisions based on the functions that are currently being provided, irrespective of their theoretical sustainability.
3. There are numerous situations where an entity may want to assess wetlands for a particular function and want to know which ones perform that function at the highest level, regardless of whether it had been altered or not. For example, if a city public works department decided that the most cost-effective way to manage stormwater was to purchase all of the wetlands that did a good job of detaining flood flows, they might want to assess all wetlands in their jurisdiction for that particular function. They would not care how these wetlands compared to the least altered condition - they would want to know which ones actually perform the function at the highest level. In another case, a land manager or agency may want to protect all wetlands that provide habitat for a certain group of species (such as salmon) and they would want to be able to assess for that particular function.

Concerns Regarding Use of the WFAP Approach

Management Implications

The primary concern that has been expressed about the WFAP Approach is that it could lead to the maximization of certain functions at the expense of others. The concern is that certain enhancement techniques could raise an individual function score by altering a relatively "natural" wetland. First, this may be appropriate for certain management situations. Secondly, the WFAP Approach will allow a manager to see how other functions are affected when one or two are maximized. In most cases, as one function is increased, others will decrease. Under the WFAP Approach, decisions about how to "value" or manage for certain functions is left to the decision-making process instead of being "decided" by the method a priori.

Another concern with the WFAP Approach is that a relatively unaltered wetland may score low for some or many functions because it lacks the particular environmental characteristics that contribute to those functions. This means that a "pristine" wetland could be "undervalued" by a decision-maker because of its low function scores. The solution to this concern is to recognize that there are other factors besides performance of functions that need to be considered in decision-making (see 2.2.2) including the rarity, sensitivity, or irreplaceability of a wetland.

Appendix E: Summary of Assessment Models for Western Washington Lowland Wetlands

Summary of Assessment Models for Western Washington Lowland Wetlands

***Note**: In the model summaries below, only the numerator of the equation is shown. The denominator for each equation is the score from the reference standard wetland. Variables shown in bold are the variables that are reducers of performance.*

Potential for Removing Sediment	
Riverine Flow-through	
Index =	(Vflowpath + 2 x Vau/stream + Vvegclass + Vunderstory) x **Vdikes**
Riverine Impounding	
Index =	Vstorage + Vout + Veffectarea1 + Vvegclass + Vunderstory
Depressional Outflow	
Index =	Vstorage + Vout + Veffectarea1 + Vvegclass + Vunderstory
Depressional Closed	
Index =	10 - All wetlands perform the function at maximum potential
Potential for Removing Nutrients	
Riverine Flow-through	
Index =	Ssed
Riverine Impounding	
Index =	(Ssed + Vsorp) + Veffectarea2 + Vout
Depressional Outflow	
Index =	(Ssed + Vsorp) + Veffectarea2 + Vout
Depressional Closed	
Index =	Vsorp + Vvegcover
Potential for Removing Metals and Toxic Organics	
Riverine Flow-through	
Index =	Ssed + Vph + Vtotemergent
Riverine Impounding	
Index =	Ssed + Vsorp + Vph + Vtotemergent + Veffectarea1
Depressional Outflow	
Index =	Ssed + Vsorp + Vph + Vtotemergent + Veffectarea1
Depressional Closed	
Index =	Vsorp + Vph + Vtotemergent + Veffectarea1
Potential for Reducing Peak Flows	
Riverine Flow-through	
Index =	Vau/stream + 2 x Vau / shed
Riverine Impounding	
Index =	Vlivestorage + Vout + Vinund / shed
Depressional Outflow	
Index =	Vlivestorage + Vout + Vinund/shed
Depressional Closed	
Index =	10 - All wetlands perform the function at maximum potential
Potential for Decreasing Downstream Erosion	
Riverine Flow-through	
Index =	(Vwoodyveg + Sredpkflow) x **Vdikes**
Riverine Impounding	
Index =	½ x / Vlivestorage + Vwoodyveg + Vout + 2 x Vinund / shed
Depressional Outflow	
Index =	½ x / Vlivestorage + Vwoodyveg + Vout + 2 x Vinund / shed

Depressional Closed	
Index =	10 - All wetlands perform the function at maximum potential
Potential for Recharging Groundwater	
Riverine Flow-through	
Index =	Vinfilt + Vau / ratio
Riverine Impounding	
Index =	Vinfilt + Veffectarea2
Depressional Outflow	
Index =	Vinfilt + Veffectarea2
Depressional Closed	
Index =	Vinfilt + Veffectarea2
General Habitat Suitability	
Riverine Flow-through	
Index =	(Vbuffcond + V%closure + Vstrata + Vsnags + Vhydrop + Vvegintersp + Vlwd + Vprichness + Vmature + Vedgestruc + Vwintersp) x **Vupcover**
Riverine Impounding	
Index =	(Vbuffcond + V%closure + Vstrata + Vsnags + Vvegintersp + Vlwd + Vhydrop + Vwaterdepth + Vwintersp + Vprichness + Vmature + Vedgestruc) x **Vupcover**
Depressional Outflow	
Index =	(Vbuffcond + V%closure + Vstrata + Vsnags + Vvegintersp + Vlwd + Vhydrop + Vwaterdepth + Vwintersp + Vprichness + Vmature + Vedgestruc) x **Vupcover**
Depressional Closed	
Index =	Vbuffcond + V%closure + Vstrata + Vsnags + Vvegintersp + Vlwd + Vhydrop + Vwaterdepth + Vwintersp + Vprichness + Vmature + Vedgestruc) x **Vupcover**
Habitat Suitability for Invertebrates	
Riverine Flow-through	
Index =	Vpermflow + Vsubstrate + Vwintersp + Vlwd + Vstrata + Vaquastruc + Vvegintersp + Vassemb
Riverine Impounding	
Index =	(Vpermflow + Vsubstrate + Vwintersp + Vlwd + Vstrata + Vvegintersp + Vassemb + Vhydrop + Vaquastruc) x (**Vtannins**)
Depressional Outflow	
Index =	(Vpermflow + Vsubstrate + Vwintersp + Vlwd + Vstrata + Vvegintersp + Vassemb + Vhydrop + Vaquastruc) x (**Vtannins**)
Depressional Closed	
Index =	(Vsubstrate + Vwintersp + Vlwd + Vstrata + Vvegintersp + Vassemb + Vhydrop + Vaquastruc) x (**Vtannins**)
Habitat Suitability for Amphibians	
Riverine Flow-through	
Index =	(Vbuffcond + Vsubstrate + Vpermflow + Vpools + Vlwd) x (**Vphow or Vupcover**)
Riverine Impounding	
Index =	(Vbuffcond + Vsubstrate + Vwintersp + Vlwd + Vwater + Vsubstruc) x (**Vphow or Vupcover**)
Depressional Outflow	
Index =	(Vbuffcond + Vsubstrate + Vwintersp + Vlwd + Vwater + Vsubstruc) x (**Vphow or Vupcover**)
Depressional Closed	
Index =	(Vbuffcond + Vsubstrate + Vwintersp + Vlwd + Vwater + Vsubstruc) x (**Vphow or Vupcover**)
Habitat Suitability for Anadromous Fish	
Riverine Flow-through	
Index =	2 x Vflowmods + 2 x Vcover + V%closurest + Vstreamsubs
Riverine Impounding	
Index =	(Vwintersp + Vwaterdepth + 2 x Vcover + Vpow + Sinverts) x **Vbogs**
Depressional Outflow	
Index =	(Vwintersp + Vwaterdepth + 2 x Vcover + Vpow + Sinverts) x **Vbogs or Vculverts**
Depressional Closed	

	Function not performed
Habitat Suitability for Resident Fish	
Riverine Flow-through	
Index =	2 x Vpermflow + Vcover + V%closurest + Vstreamsubs + Vwaterdepth
Riverine Impounding	
Index =	Vwintersp + Vwaterdepth + Vcover + Vpow + Vpermflow + Vsubstrate + Sinverts
Depressional Outflow	
Index =	Vwintersp + Vwaterdepth + Vcover + Vpow + Vpermflow + Vsubstrate + Sinverts
Depressional Closed	
	Function cannot be assessed in rapid method
Habitat Suitability for Wetland Associated Birds	
Riverine Flow-through	
Index =	(Vsnags + Vvegintersp + Vspechab + Vpow + Vbuffcond + Sinverts + Samphib + Sfish) x (**Velev or V%closure**)
Riverine Impounding	
Index =	(Vbuffcond + Vsnags + Vvegintersp + Vspechab + Vpow + Vedgestruc + Sinverts + Samphib + Sfish) x (**V%closure**)
Depressional Outflow	
Index =	(Vbuffcond + Vsnags + Vvegintersp + Vspechab + Vpow + Vedgestruc + Sinverts + Samphib + Sfish) x (**V%closure**)
Depressional Closed	
Index =	(Vbuffcond + Vsnags + Vvegintersp + Vspechab + Vpow + Vedgestruc + Sinverts + Samphib) x (**V%closure**)
Habitat Suitability for Wetland Associated Mammals	
Riverine Flow-through	
Index =	(Vbuffcond+Vwaterdepth+Vcorridor+Vbrowse+Vemergent2 + Vbank + Vpermflow + Sfish) x (**Vupcover**)
Riverine Impounding	
Index =	(Vbuffcond + Vwaterdepth + Vcorridor + Vbrowse + Vemergent2 + Vwintersp2 + Vow + Vbank + Vpermflow + Sfish) x (**Vupcover**)
Depressional Outflow	
Index =	(Vbuffcond + Vwaterdepth + Vcorridor + Vbrowse + Vemergent2 + Vwintersp2 + Vow + Vbank + Vpermflow + Sfish) x (**Vupcover**)
Depressional Closed	
Index =	(Vbuffcond + Vwaterdepth + Vcorridor + Vbrowse + Vemergent2 + Vwintersp2 + Vow + Vbank) x (**Vupcover**)
Richness of Native Plants	
Riverine Flow-through	
Index =	(Vnplants + Vstrata + Vassemb + Vmature) x (**Vnonnat**)
Riverine Impounding	
Index =	(Vnplants + Vstrata + Vassemb + Vmature) x (**Vnonnat**)
Depressional Outflow	
Index =	(Vnplants + Vstrata + Vassemb + Vmature + Vbogs) x (**Vnonnat**)
Depressional Closed	
Index =	(Vnplants + Vstrata + Vassemb + Vmature + Vbogs) x (**Vnonnat**)
Primary Production and Export	
Riverine Flow-through	
Index =	(Vvegcover + Vnonevergreen + Vunderstory)
Riverine Impounding	
Index =	(Vvegcover + Vnonevergreen + Vunderstory) x (Vorg + Vout)
Depressional Outflow	
Index =	(Vvegcover + Vnon-evergreen + Vunderstory) x (Vorg + Veffectarea1) x **Vbogs**
Depressional Closed	
Closed systems do not perform the function.	